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POUR L'EXPLORATION DE LA MER

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VOL. VI · NO. 2

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E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

Août 1931

Note.

The Journal of the Council will in future appear *three times a year*, and three numbers will form a volume. It will include, in addition to general articles, reviews and bibliography, the special papers hitherto issued in the series of "Publications de Circonstance".

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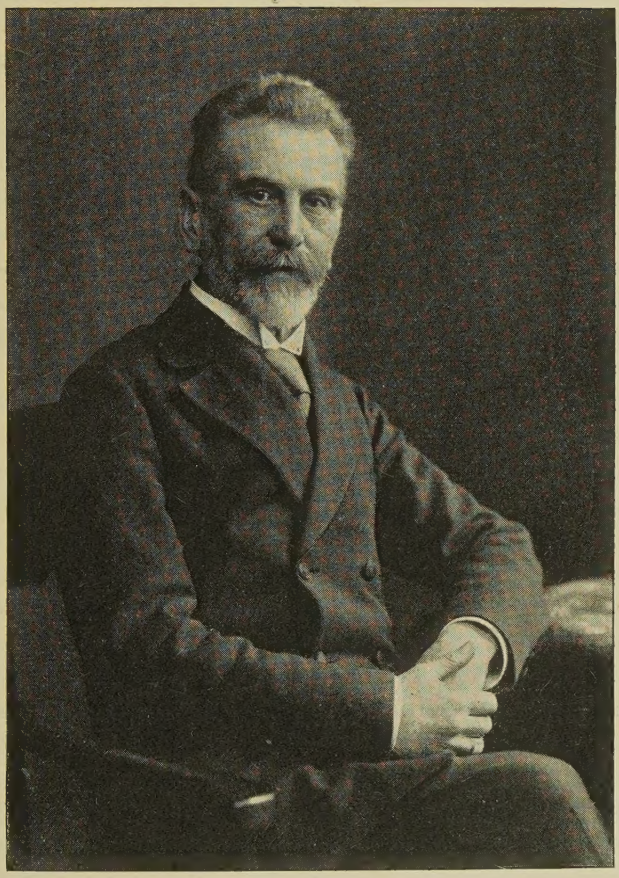


Karl Brandt,

gestorben am 7. Januar 1931.

Karl Brandt ist am 23. Mai 1854 in Magdeburg geboren. Er studierte Naturwissenschaften hauptsächlich in Berlin und promovierte 1877 in Halle mit einer Arbeit über Actinosphaerium zum Dr. phil. Von 1878—82 war er Assistent am Berliner physiologischen Institut unter Dubois-Reymond, arbeitete von 82—85 an der Zoologischen Station in Neapel und ging von da nach

Königsberg, wo er sich im Juli 1885 als Privatdozent für Zoologie habilitierte. Im April '87 wurde er mit der Vertretung von Karl Möbius betraut, dessen Nachfolger er ein Jahr später als Professor der Zoologie und als Direktor des Zoologischen Instituts und Museums der Kieler Universität wurde. Von 1887 bis 1913 hielt Brandt auch Vorlesungen an der Marineakademie. Von 1888 an war er Mitglied der Preussischen Kommission zur wissenschaftlichen Untersuchung der deutschen Meere, trat im Februar 1901 bei der Gründung der Deutschen wissenschaftlichen Kommission für internationale Meeresforschung auch dieser als Mitglied bei und leitete ihr Kieler Biologisches Meereslaboratorium. Im Oktober 1922 wurde Brandt von seinen amtlichen Verpflichtungen der Universität gegenüber entbunden, arbeitete aber bis zu seinem Tode an der Lösung von Aufgaben aus dem Gebiete der Meeresforschung weiter, die ihm reiche Förderung verdankt.

Brandt's wissenschaftliche Tätigkeit ging von der Untersuchung einzelliger Tiere aus, an denen neben dem Bau besonders die Entwickelung und die Anpassungen an die Umwelt ihn fesselten. Als grundlegende Arbeiten aus diesem Gebiete seien neben seiner Dissertation über Actinosphaerium die »Monographie der koloniebildenden Radiolarien« aus Neapel und »Die Tintinnen« als ein Ergebnis seiner Teilnahme an der Plankton-Expedition genannt. Von allergrösster Bedeutung ist aus seiner Neapler Zeit aber die Feststellung über das Wesen der »Gelben Körperchen«, der Zooxanthellen, im Plasma der Radiolarien geworden, deren Natur als einzellige Algen Brandt wissenschaftlich einwandfrei klarlegte und dadurch der Mitbegründer der Lehre von der Symbiose in der besonderen Form des Aufenthalts von einzelligen Pflanzen in lebenden Tierzellen wurde. Diese Forschungen bildeten aber auch die Brücke zu seinem späteren Hauptarbeitsgebiete, dem Stoffumsatz im Meere.

In Kiel beschäftigten Brandt zunächst Fragen nach dem Einfluss der Konzentration des Salzgehaltes des Meerwassers auf die Seetiere. Es war das ein Aufgabenkomplex, mit dem sich schon Möbius eingehend befasst hatte. Brandt stellte in ausführlichen Tabellen die Abnahme in der Zahl der Tierarten von der Nordsee über Kattegat und westliche Ostsee bis in den Finnischen und Bottnischen Busen hinein dar und verfolgte auch die Wirkung

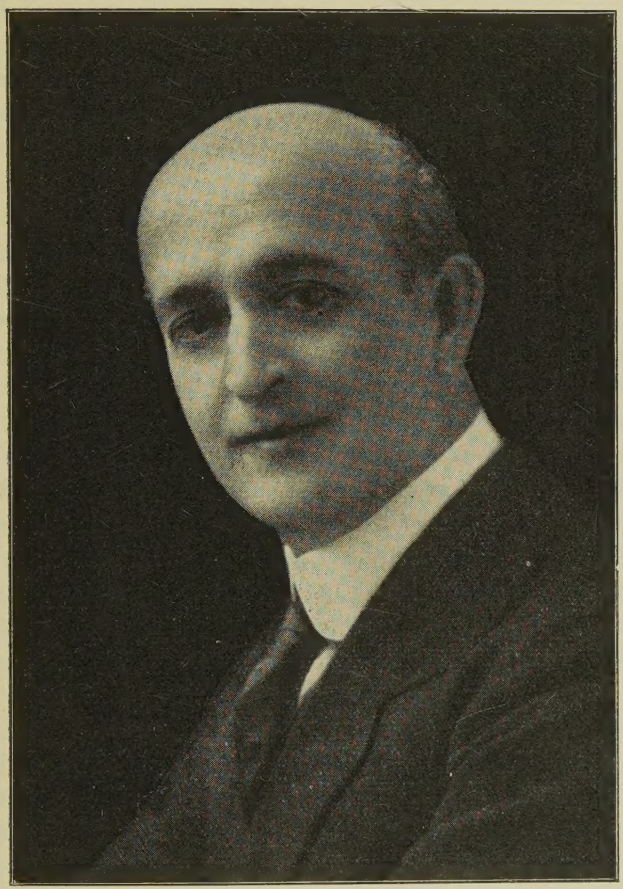
des verminderten Salzgehaltes auf Grösse und relative Schalendicke bei einer Reihe euryhaliner Mollusken, die von der Nordsee bis in die östliche Ostsee hinein auftreten. Nach Vollendung des Nord-Ostsee-Kanals untersuchte Brandt das Vordringen von Meerestieren vom Kieler Hafen aus in dem von der Elbe her mit Süsswasser gespeisten Kanal längere Zeit hindurch und wertete so ein Experiment wissenschaftlich aus, wie es in so grossen Ausmassen nur selten sich darbietet.

Von entscheidendem Einfluss auf die Richtung, die Brandt's Forschungen über den Stoffwechsel nehmen sollten, wurde in Kiel aber sein Zusammenarbeiten mit Victor Hensen, dessen Methoden der quantitativen Planktonforschung es ihm ermöglichten, Vergleiche zwischen den durch quantitative chemische Analyse feststellbaren gelösten Pflanzennährstoffen des Meeres und der Menge der sie verarbeitenden Pflanzen durchzuführen und daneben dem Mengenverhältnis von produzierenden Pflanzen und konsumierenden Tieren nachzugehen. Das Liebig'sche Gesetz vom Minimum, auf dessen Anwendbarkeit auf die Pflanzenerzeugung im Meere Brandt seine Lehre stützte, wird jetzt allgemein als eine der Grundlagen des Stoffumsatzes im Meere anerkannt. In Emil Raben hatte Brandt einen Mitarbeiter gewonnen, der mit grossem Erfolg die Verfeinerung der Methoden zur quantitativen Feststellung der im Meerwasser spurenweise vertretenen Pflanzennährstoffe (Phosphorsäure, Nitrat, Kieselsäure) gefördert hat. Aber auch die späteren zum Teil ganz wesentlichen Verbesserungen dieser Technik hat Brandt ständig seinem Lehrgebäude nutzbar gemacht, dem er später auch noch die energetischen Wachstumsfaktoren Licht und Wärme einfügte.

Brandt's Abhandlungen zum Stoffwechsel im Meere sind hauptsächlich in den »Wissenschaftlichen Meeresuntersuchungen, Abtlg. Kiel«, in den »Rapports et Procès-Verbaux des Réunions« und in den »Berichten der Deutschen Wissenschaftlichen Kommission für Meeresforschung« erschienen.

Der Tod hat Karl Brandt mitten in der Arbeit ereilt: die steigende Anerkennung seiner wissenschaftlichen Lebensarbeit hat seinen Lebensabend verschönt!

J. REIBISCH.



David Thomas Jones.

(1866—1931).

The sudden death, on 4th February, 1931, after a short illness, of David Thomas Jones, Chairman of the Fishery Board for Scotland, has closed a remarkable career, and has removed a capable administrator, whose intimate knowledge and wide experience of the Fishing Industry in all its complex and varied problems were unrivalled.

To appreciate the romance of JONES' life it is necessary to explain the constitution and functions of the Scottish Fishery Board. The Board was constituted by Act of Parliament in 1882, although a previous board had existed for the protection and encouragement of the herring fishing, the oldest Act of Parliament for regulating the industry still in force having been passed in 1705.

The function of the Board is to supervise and conserve the interests of the Scottish fishing industry. Statistics are regularly compiled; branding, which was originally instituted by the British Government in 1809, is still carried on by the Fishery Board as a means of guaranteeing the quality of the cured herrings; a fleet of patrol steamers is maintained for the protection of the fisheries; Inshore fisheries are regulated by means of Bye-laws which the Board are empowered to make; conflicting interests between fishermen, and curers, and other persons concerned in the industry are adjusted. The Board also supervise the important Salmon Fisheries and control and regulate by licence the Whaling industry. They carry on Marine research work on an extensive scale and supervise the large public expenditure which has been, and is being, incurred in the repair, re-construction and extension of Fishery Harbours. It will readily be seen that to become master of such a varied organisation was no easy task.

JONES was born in 1866 at Gilfach Goch, in Glamorganshire South Wales, where he was educated. In May 1886 he became a Junior Clerk in the Civil Service through his success in open competition. In 1887 he was appointed to the Fishery Board for Scotland; and the young Welshman came to Edinburg, an entire stranger, to enter upon what was destined to be the scene of his life's labour. At the outset JONES was somewhat handicapped. He was in a new environment and wholly unacquainted with the peculiarities of the Scottish character. From the first JONES was characterised by assiduity, versatility, and adaptability and by a readiness to seize every opportunity of self-improvement with the result that in 1892 he became Chief Clerk, and in 1909 he was appointed by Royal Warrant Secretary of the Fishery Board.

It is not too much to say that the high state of efficiency to

which the Board in its various Departments attained, and still maintains, was largely due to JONES' perspicacity, foresight, resource and untiring zeal and energy during the years he was Secretary.

It was therefore a matter of no surprise when, on a vacancy occurring in 1920, a radically new departure was made, and JONES was appointed Chairman of the Board. This appointment was an achievement of which JONES was justly proud, not only on personal grounds, but owing to its being then one of the rare, if not the only, instance in Scotland of a Civil Servant rising, from a junior clerkship, to the Chairmanship of his Department.

As Chairman, JONES evinced the same capacity and ability as he had done formerly. After the War his knowledge of fishery interests and personnel was of the highest use in connection with demobilisation, and the many other difficult matters which thereafter arose.

As one of the British delegates to the International Council for the Study of the Sea JONES took an active and deep interest in all its deliberations. He was a member of several of its Committees and latterly Chairman of the combined Committees which conducted the Marine investigations of the Northern and Southern parts of the North Sea. The appreciation of his usefulness and the esteem he was held in by his International colleagues was strikingly shewn by the numerous communications of sympathy expressed on his death, the key to which was aptly expressed by one who wrote of him as 'this kindly man, always cheerful and helpful'.

JONES' activities were not merely confined to his official duties. In 1920 he attended the International Labour Conference at Genoa as an adviser on fishery matters, and in 1924 he visited British Columbia for the purpose of investigating the possibilities there for the settlement of crofter fishermen from the Western Islands of Scotland. He also served on numerous Government Committees dealing with post War problems.

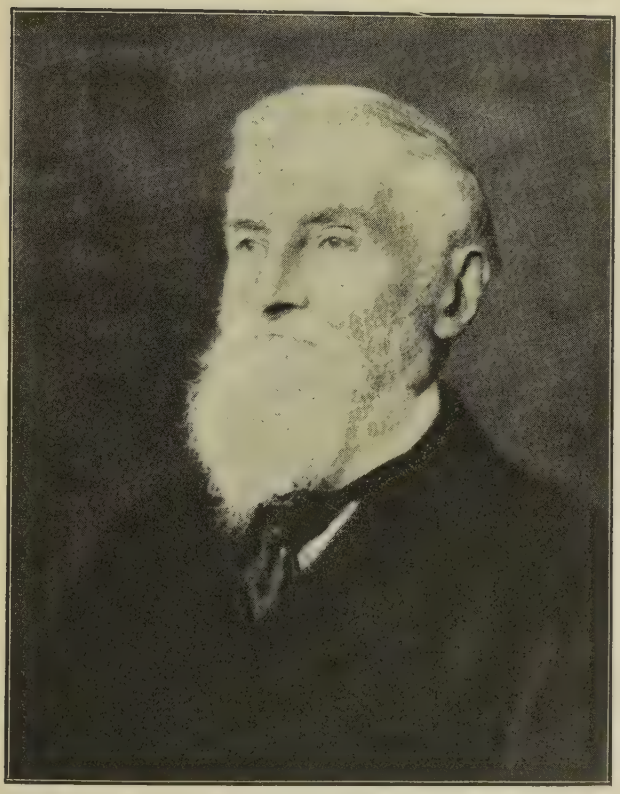
In his younger days JONES had been an active Volunteer and held a commission in the Q.E.R.V.B. (Royal Scots). In 1914 he was commissioned as Paymaster Lieutenant Commander, R.N.R., and gazetted C.B.E. (Military) and C. B. E. (Civil) in 1919 for special services during the War.

JONES was a Fellow of the Royal Society of Edinburgh, and of the Royal Statistical Society.

In private life JONES had many interests. True to his nationality he was a musician of no mean order, and in his youth was much interested in athletics and a keen golfer to the last.

Every one who knew him esteemed his friendship, his sterling worth and charming personality. And a blank has been created by his death which time alone can efface.

W. L. M.



William Carmichael M'Intosh.

(1838—1931).

William Carmichael M'Intosh was born at St. Andrews on 10th October 1838 and died there on 1st April 1931. He was educated at Madras College, St. Andrews and at the University of St. Andrews, afterwards at the University of Edinburgh, where he obtained the degree of M. D. at the age of 23. He was at once appointed as Assistant Physician to the Murray's Royal Asylum at Perth and three years later as Medical Superintendent to the Perth District Asylum, a position he held from 1863 to 1883. In 1882 he was elected to the Chair of Natural History in the University of

St. Andrews and thus entered upon a career which inclination and early training had clearly indicated.

The abundance and variety of marine life in St. Andrews Bay attracted W. C. M'Intosh as a boy and a youth. The shallow sands on the one side and the rocky shore on the other yielded periodical riches which he early began to collect and to study. The thesis he presented for the M. D. of Edinburgh bore the title "Observation and Experiments on *Carcinus maenas*" and contained interesting details relating to habit and structure and the influence of drugs. Like the other naturalists of the period he chose a group for special study and his choice was the worms of the sea. With the aid of his sister, careful and artistic drawings were made and structure was studied with the aid of dissection and such methods as were then known in microscopic preparation. Even when he was at Perth his visits home and sympathetic and helpful members of his family kept him supplied with material.

As a result we have the splendid series of volumes published by the Ray Society and which have been and will be so useful to marine zoologists. The first volume on the Nemerteans was published in 1874. The other volumes on the Polychaets occupied him during a long life up to 1923. The examination and report upon the Polychaets obtained during the voyage of the Challenger and of similar material sent to him from other expeditions led to interesting results relating to the distribution of forms subject to the current movements of the sea. Naturalists like Gwynn Jeffreys and Canon Norman sent to him the annelids of their dredging excursions in western and northern parts of the seas of the British Isles, and Whiteaves contributed specimens from the Gulf of St. Lawrence, and he was able to indicate and to discuss the relative productivity of many regions.

He was not, however, merely a specialist. During the earlier part of his career his papers showed that he was interested in other marine and land groups. A volume which he published in 1875 on the Marine Invertebrates and Fishes of St. Andrews showed the wide range of his observations, and a second volume on the same subject was issued as recently as 1927. His long contact with marine zoology made him an expert in every phase of it, and he had an intimate systematic knowledge of every group. He was

always aware of the problems relating to such. This was illustrated by his description of *Cephalodiscus* and the demonstration of peculiarities which related it to Rhabdopleura. It is a pity that we still know so little about both.

Addresses and papers in the early'eighties also showed how desirous he was to get a Marine Laboratory established at St. Andrews. In 1884 he was able to realise this ambition. A Fever Hospital which had been built on the tongue of land between the harbour and the sea became available and was secured. It was simply but quite adequately adapted for the purpose. An outhouse served as a pump room. A large room was provided with tanks and a large and two small rooms were fitted as laboratories. One of these small rooms was reserved for the use of the Professor. At once this small marine station became an attractive and welcome centre of work, especially during the long vacation, to many workers from a distance, as well as postgraduate students of the University. Some of them, alas, are now dead but some still occupy important positions in Natural History and in Fishery administration.

It was during this period that the work on the development of fishes was undertaken and pursued with zeal. In this Professor M'Intosh was ably assisted by Professor Prince and by the Laboratory Fisherman and Steward, A. Wallace Brown. Brown, in spite of a lack of education, was intelligent and very efficient. He not only looked after the general work of the Laboratory and the pumping of the water, but every day practically he went out alone in the morning in a cutter and worked different forms of nets. The products were brought back alive to the harbour and to the Laboratory. Brown soon got to know the material required by each of the workers and he divided his captures accordingly. He developed also a knowledge of the eggs of fishes, and if anything new in this respect or anything unusual otherwise was seen, such was carefully set aside pending the coming of the Professor.

Every afternoon, when he was at home (and he did not absent himself very often), he arrived punctually at the harbour, was ferried across by Brown, and he immediately proceeded to examine the living material. He was a good worker and the results are well known in a succession of papers published by the Fishery Board for Scotland, the Royal Society of Edinburgh, and in the book,

written in collaboration with A. T. Masterman, on the Food Fishes of Britain. After he had finished, or at least sometime during the afternoon, he visited the general laboratory room and chatted with the workers, discussing in the most friendly and helpful manner results and implications.

More intimate conversations were possible at his house in Abbotsford Crescent and the garden parties at Cupar and, later, at his estate at Nevay were attractive functions at which one was liable to meet the eminent men of the day in Natural History and Medicine.

Before the Marine Laboratory was established at St. Andrews, Professor M'Intosh began his enquiries relating to the effects of trawling and reported in 1884 to the Royal Commission the results of his enquiries. He continued to interest himself in the trawling experiments of the Fishery Board for Scotland, and the fluctuations in the Fisheries which it was hoped they would elucidate. But impressed as he had been in early years with the richness and immense recuperative capacity of the life of the sea, he was disinclined to advise measures of protection the effect of which would be to hamper fishing and to promote poaching. His work entitled the "Resources of the Sea", which was issued in 1899, and "A Second Decade" in 1903, conveyed the analyses upon which he based such a conclusion. The subject is still one of debate and his opinion, the general tendency of which must be admitted to be right, must still receive due consideration. And this is true also of his views with respect to international investigations.

Professor M'Intosh was a bachelor, a non-smoker and a teetotaler. He devoted himself earnestly to every duty which his position and work called for. The regular routine of his days at St. Andrews was interrupted only by a holiday which was largely, as he expressed it, a change of work, and by visits to Edinburgh and London to attend meetings of societies in the work of which he was interested. He has left behind him a record of work which could scarcely be equalled, for he was working up to the time of his death. His papers and books number about 300.

The old Marine Laboratory was given up in 1896, when the new Gatty Marine Laboratory was opened and in the latter the work was continued until the war. Then it was closed and it is

more than a pity that it has not again been opened. From the traditions associated with it and the importance of the region, no better memorial could be suggested to this eminent Marine Naturalist of St. Andrews than to recondition and re-establish the Marine Laboratory and to indicate that it is done to perpetuate his memory.

A. M.

Carl Hansen Ostenfeld.

1873–1931.

Through the death of Professor Carl Hansen Ostenfeld the International Council for the Exploration of the Sea has lost one of its oldest and most active members.

Ostenfeld began his marine work when as a young student he took part in the "Ingolf"-expedition in the years 1895 and 1896. On this occasion he and Martin Knudsen carried out the well known experiment on the influence of the plankton algae on the tension of oxygen and carbonic acid in sea water. In the following

years (1897—1899) together with WANDEL and MARTIN KNUDSEN he organized hydrographical and biological investigations along the Danish steamship routes to Iceland and Greenland. He studied the occurrence of the plankton associations at different seasons and their dependance on the hydrographical variations.

From the year 1900 OSTENFELD was a member of the Danish Commission for the Investigation of the Sea and from 1902 the leader of its plankton department. In 1902 he was present for the first time as expert at the meeting of the International Council and worked out, in conjunction with CLEVE, the plan for the plankton investigations to be made during the quarterly cruises. From that year he was regularly present at the meetings, in the later years as chairman of the Plankton Committee. He did an invaluable service to the International scheme of cooperation as Editor of the three large volumes of the Plankton Résumé, giving in a clear form the complete results of the numerous observations collected during the quarterly cruises during the years 1901—1908 and published as tables in the bulletins. He himself wrote the chapter on the diatoms. In his last year he finished the fourth volume, giving the general results of the whole work. These volumes will long remain an indispensable manual of the biology of the species of pelagic plants and animals living in North European waters.

OSTENFELD had an extensive knowledge of the taxonomy and biology of the plankton algae. He published a series of papers on plankton from widely different regions: the Caspian Sea, the Red Sea (with JOHS. SCHMIDT), Siam, the Benguela current, Victoria Nyanza, the Aral Sea and East Greenland. Of special interest was his investigation of *Biddulphia sinensis*, which occurred suddenly in the North Sea in November 1903, probably having been introduced from East Asia, propagated in its new area and drifted with the currents into the Skagerrak and Kattegat and northwards along the Norwegian coast.

OSTENFELD's largest work on marine biology is his investigation of the plankton of the Danish waters in the years 1898 to 1901, published in 1913. It contains a large number of exact observations on the occurrence of all the species at different seasons at a number of well selected stations. The great variations in tem-

perature and salinity characteristic of this area gave him an excellent opportunity to study the manner in which the various species are dependent on these variations, and in the general chapters he gives a sound critical statement on our knowledge of the biology of the phytoplankton.

OSTENFELD's work on marine subjects represents only a minor part of his scientific production. As the leading botanist in Denmark for several years he has published a great number of papers on the taxonomy and distribution of the higher plants, and his experiments on castration and hybridization with some species of *Hieracium* are of fundamental value. He knew the phanerogamous plants of Northern Europe and the Arctic regions as few other botanists do.

OSTENFELD had a clear and critical mind, and his extraordinary capacity was extensively made use of in administrative work. In our organization we shall miss him not only as a thorough and conscientious collaborator, but also as a friend.

H. H. GRAN.

Digestive Processes in Marine Invertebrates and Fishes.

By

C. M. Yonge,

Physiologist at the Plymouth Laboratory.

1. Introduction.

The steady development of the science of comparative physiology is continually providing new and most valuable knowledge for the marine biologist. In no case is the value of this new source of knowledge more apparent than in the nutrition of marine animals. Food is one of the fundamental factors controlling the abundance and distribution of marine life. Accurate quantitative surveys of the plankton or bottom fauna have long been recognized as an essential preliminary to the estimation of the potential productiveness of any region. The mode of feeding in the great majority of marine organisms has been studied in considerable detail (see YONGE (1928a) for a general survey) and exhaustive examinations of the stomach contents of many marine animals, especially those of economic importance, have been made. Yet the marine biologist has failed in many cases to recognize the equal importance of an accurate knowledge of the digestive processes of the animals with which he works. Digestion has been taken for granted.

It has been stated elsewhere in a survey of the feeding mechanisms of invertebrates (YONGE (1928a)) that there are well defined correlations between (1) the habitat and available food of any animal, (2) the type of feeding mechanism, (3) the structure of the alimentary system, and (4) the nature of the digestive processes and the relative strength (or presence and absence) of the various digestive enzymes. In that paper an account was given of specializations of the feeding mechanisms, facts which are sufficiently clear to all marine biologists. In this paper the equally wide-spread and equally important specializations of the digestive processes, especially of the enzymes concerned in the breaking down of the food, will be discussed. The presence of these specializations

has never been sufficiently realized by marine biologists. They have been in the habit of regarding an examination of the stomach contents of any animal as furnishing an adequate indication of the food of that animal. Actually they have obtained information as to what the animal may collect and pass into its alimentary system. This may or may not indicate the true food of the animal. This matter will be discussed in detail in the concluding section of this paper after the digestive processes in the various groups of marine animals have been surveyed.

Marine biologists have been at a great disadvantage owing to the very scattered nature of the literature on the comparative physiology of digestion. One of the objects of this paper has been to collect and survey this literature in form and place where it will be easily available. There are many gaps in our knowledge some of which, it is hoped, may be filled as a result of the publication of this paper. Particular stress has been laid on recent work or older papers of especial value, for a complete bibliography of work on the subject (much of which is of historical interest only) reference should be made to the works of Biedermann (1910) and Jordan (1913). Although this paper is concerned with marine animals, some reference has also been made to work on freshwater or terrestial animals because in many cases (e. g. *Hydra* in the Coelenterata, *Astacus* in the Crustacea, and *Helix* in the Gastropoda) they have been more exhaustively studied than allied marine species. Knowledge of their digestive processes is, therefore, of considerable comparative value. Parasites and groups which are practically confined to the land and to fresh water (notably the Insecta and Arachnida) are not considered, nor, with the exception of a passing reference, are the Protozoa.

2. Porifera.

In the **Protozoa**, with the exception of a few cases, such as *Vampyrella* (Lloyd (1926)) where an extruded cellulase enables the animal to digest its way through the cellulose walls of plants, digestion is *intracellular*. Minute particles of food are engulfed within the protoplasm, either at an especial "mouth" or, as in *Amoeba*, wherever they happen to touch the surface of the animal. Within the particles come to lie in vacuoles, the reaction in which is usually first acid and then alkaline. It is in the latter phase, apparently, that the digestive enzymes in the vacuoles act upon the food.

In the **Porifera** conditions are essentially the same. The stream created by the beating of the flagella on the collar cells in the flagellated chambers draws in with it many fine particles and nannoplankton.

These are ingested phagocytically by the collar cells, both at the sides and within the collars (Cotte (1904), van Trigt, 1919). According to van Trigt, in the freshwater sponges (Spongillidae) particles too large to pass the prosopyles are ingested there within the layer of undifferentiated protoplasm. In either case the food is passed to amoebocytes where it is digested. According to Cotte, who worked on a great variety of marine sponges, the reaction within these vacuoles is first acid and then, after about six hours, becomes alkaline when digestion takes place. The initial acid phase, here as in the **Protozoa**, is generally considered to favour the destruction of bacteria. Cotte found a protease which digested proteins in alkaline media (Roaf (1908) on the contrary states that extracts of *Clione celata* digest protein in acid media), and also enzymes which acted upon the three carbohydrates, starch, saccharose and raffinose, and also on fats. According to Cotte the faeces are rejected by way of the inner side of the collar cells, but van Trigt states that in freshwater sponges defecation never occurs there, but probably on the outer surface of the sponge.

No accurate quantitative work has been carried out on the digestive enzymes of sponges. Their digestive processes resemble exactly those of the **Protozoa**. They are probably the only free living Metazoa in which digestion is *exclusively intracellular*.

3. Coelenterata.

In spite of the apparent dissimilarity between the diverse groups comprising the **Coelenterata**, their digestive processes are, in all essentials, identical. It is noteworthy that the coelenterates are *exclusively carnivorous*, paralysing their prey with nematocysts and then conveying it to the mouth usually by tentacular action, which may be assisted or superceded by ciliary action. This is particularly well exemplified in the **Madreporaria** (Yonge (1930b)).

Within the coelenteron the animal prey is broken down by the action of a powerful *extracellular* protease. This is secreted by gland cells which are scattered through the endoderm in the case of the **Hydrozoa**, and confined to the rounded margins of the mesenterial filaments in the **Anthozoa**. In the **Schyphozoa** the gastric filaments may be concerned with secretion. No other enzymes have been identified within the coelenteron. After it has been reduced by enzymatic action to fluid or fine particles, the food is ingested phagocytically and digestion is completed by means of intracellular enzymes within vacuoles in the cells of the endoderm. In the **Hydrozoa** and **Scyphozoa**, assimilation is

carried out by the endoderm cells generally, but in the **Anthozoa** this process is restricted to that zone of the mesenterial filaments immediately within the rounded, glandular margin.

In the **Hydrozoa,** most work has been done on *Hydra*, the most recent work being that of Beutler (1924, 1927). An extracellular protease was demonstrated, the ph in the coelenteron being given as about 8.2, but within the digestive vacuoles it was first acid and later neutral. Olive oil could not be digested extracellularly but was converted into fine droplets by peristaltic action and then ingested phagocytically to be acted upon within the cells by an intracellular lipase. Amongst carbohydrates, glycogen was ingested phagocytically but starch was only ingested if mixed with protein. Beutler (1926) has also worked on a variety of marine hydroids and found a similar extracellular digestion of protein within the polyps, whence food is distributed throughout the hydrorhiza and vertical branches of the colony by means of ciliary movement and persitalsis. At the entrance to the stalk beneath the polyp there is a constriction which prevents the passage of large particles. Material is ingested phagocytically by the cells of the endoderm throughout the colony. Runnström (1929) states that in *Clava squamata* the endoderm forms a syncytial plasma network which assists in the ingestion and transport of food. He also notes the presence of wandering cells with granular contents which carry food.

In the **Siphonophores,** as shown by Willem (1894) who worked on *Apolemia uvaria*, the dactylozooids constitute a kind of "phagocytic stomach", and contain special funnel cells down which particles are directed by ciliary action into a digestive vacuole at the base. Bodansky and Rose (1922a) made tissue extracts of the siphons of *Physalia arethusa* and found a protease with two optima, one at ph 3.0 and the other at ph 7.3, a weak lipase, an amylase of moderate strength, a very weak maltase and an invertase, but no lactase or inulase.

In the **Scyphozoa** conditions are essentially similar. Bodansky and Rose (1922a) found precisely the same enzymes in the mesenterial filaments of *Stomolophus meleagris* as they had found in *Physalia*. Chuin (1929) states that in the scyphistome of *Chrysaora* captured zooplankton is digested very quickly by means of a transparent, viscous and acid secretion. This, besides digesting all proteins, also, according to Chuin, breaks drown chitin. The fine fragments and fluid are ingested by the endoderm where intracellular digestion takes place. He failed to find an amylase.

Considerably more work has been done on the **Anthozoa.** The presence of an extracellular protease in actinians (for many years a

subject of dispute) was first conclusively demonstrated by Jordan (1907) in *Anemonia sulcata*. He found that fibrin enclosed in bags of filter paper was dissolved out by the enzyme. Haase (1916) repeated this work but found there was no digestion of the fibrin unless there was a hole in the envelope from which the food was not more than 2 mm. distant.

Roaf (1908) made extracts of the mesenterial filaments of the actinian, *Tealia crassicornis*, and found that these digested starch and maltose after incubation for 66 and 39 hours respectively, but had no action on glycogen, saccharose or lactose. Fibrin was digested, the optimum conditions being slightly alkaline. Extracts of the filaments of *Actinia mesembryanthemum* differed only in their failure to digest starch. Bodansky (1924) obtained coelenteric fluid from *Metridium marginatum* by draining and later cutting open animals which had been fed. This fluid showed a feeble action on protein in neutral or slightly acid media and on starch. This action was much weaker after filtering the fluid and Bodansky thought that the enzymes might originate, at any rate in part, from the food. In the case of the amylase he was probably correct. Extracts of the mesenterial filaments contained a weak protease, with the same two optima as were found in *Physalia*, the "tryptic" at pH 7.3 being the more powerful, and also a weak lipase, an amylase and a maltase, but no lactase or invertase.

In the **Madreporaria** Boschma (1925) found that an extract of the entire polyps of *Astrangia danae* partially dissolved crab-meat after 4 days, and he was able to demonstrate the presence in the digest of small amounts of amino-acids. He also followed the course of digestion within the "absorptive" region of the mesenterial filaments, by means of meat coloured with Indian ink, ammonia carmine or litmus. He found that living copepods stained with neutral red and placed on the mesenterial filaments of this coral were completely digested within 3 hours, the red colour appearing within the "absorptive" zone of the filaments, and the empty skeleton alone being left. Whereas the coelenteric fluid was neutral or slightly alkaline, the reaction within the digestive vacuoles was first acid and then, after about 2 days, became alkaline.

More detailed work has been carried out by Yonge (1930c) on a variety of madreporarians. It was found that the colenteric fluid of *Fungia* has a pH of 7.8 which drops to about 7.1 after feeding. This is due to the secretion by the gland cells on the margin of the filaments of an extracellular protease which breaks down proteins to soluble polypeptides (never to amino-acids) and has an optimum pH of 7.1. No other extracellular enzymes were found. Extracts of the mesenterial

filaments of *Lobophyllia corymbosa* contained a powerful intracellular protease capable of breaking down proteins and polypeptides to amino-acids and acting best in alkaline media with an optimum at about pH 9.2. There was also a peptidase acting exclusively on dipeptides. The only other intracellular enzymes consisted of a weak lipase and a glycogenase, the later having its optimum at pH 6.5. The other carbohydrates, sucrose, raffinose, maltose, lacotose and cellulose, were not digested, nor were glucosides or pentosans. An amylase was identified within extracts of the tissues of reef corals, but it was equally abundant within all regions of the tissues. This fact indicated that it originated within the symbiotic zooxanthellae which everywhere crowd the endoderm. This was confirmed by the discovery that in *Dendrophyllia*, a coral which never contains zooxanthellae, no amylase was present.

Work on a variety of corals showed that living zooplankton was digested by them in a few hours the empty skeletons being then ejected from the coelenteron. Boschma's observations on the restriction of absorption and intracellular digestion to the "absorptive" zone immediately proximal to the glandular margin of the mesenterial filaments was confirmed (Yonge (1931a)). It was also established that this region is also the only region where excretion from the tissues takes place, and so is the only region of the coral where interchange between the interior of the tissues and exterior takes place. In the digestive vacuoles the reaction is at first about 6.4 (when digestion of glycogen and possibly fats takes place) and after about 2 days becomes alkaline, about pH 7.5, when the complete digestion of proteins to amino-acids will occur. The Madreporaria are, therefore, amongst the most highly specialized carnivores in the animal kingdom being capable only of digesting animal matter with its constituent proteins, fats and glycogen. A study of their feeding mechanisms (Yonge (1930b)) showed that they would accept only animal prey.

In the **Alcyonaria** Pratt (1906) found that in *Alcyonium* large pieces of animal food were broken down in the coelenteron by an extracellular enzyme, and that the fragments were later ingested by the cells of the ventral mesenterial filaments. A similar phagocytic ingestion of particles was found by Musgrave (1909) in *Pennatula*.

Throughout the **Coelenterata,** therefore, digestion follows the same course. Their feeding mechanisms are specialized for the effective capture, by means of tentacles armed with nematocysts, of living animal prey. Within the coelenteron an extracellular protease breaks down this prey to soluble polypeptides or minute fragments (never to amino-acids), and this material is then ingested together with minute fat globules

and glycogen. Within the tissues the preliminary extracellular digestion is completed, the fats and glycogen being digested and the polypeptides and fragments of protein being converted into amino-acids, the last process taking place in alkaline media. Amylase is frequently absent and when present very weak. Nutrition is largely confined to protein which must be converted into the carbohydrate needed for energy purposes, etc, by de-aminization. In contradistinction to the **Protozoa** and **Porifera,** digestion is no longer exclusively intracellular, but the extracellular digestion of protein is concerned only with its initial breaking down, digestion proper being still entirely an intracellular process.

In the **Ctenophora** conditions are probably closely similar. These animals also are exclusively carnivorous, and must possess an preliminary extracellular digestion of protein for, according to METCHNIKOFF (1882), digestion is intracellular.

4. Turbellaria.

While the digestive processes of marine Turbellarians have never been studied, important work has been done on a number of freshwater species. There is no reason for thinking that conditions are in any way different in marine species, and for that reason and because of the intrinsic value of this work, a short account of it is given.

The **Turbellaria** obtain their food by means of a muscular pharynx which can be greatly extended and are principally, perhaps exclusively, carnivorous. In the **Tricladida,** ARNOLD (1909), who worked on *Planaria lactea*, thought that there was both extracellular and intracellular digestion, the latter being confined to fats. LÖHNER came to similar conclusions after working on *Dendrocoelum*. WESTBLAD (1923) in an important paper on a variety of genera states that digestion is primarily, and probably exclusively, intracellular. He failed to find definite evidence of secreting cells within the gut, the cells of which are amoeboid and which take up water during digestion until they may completely fill the lumen. Syncytia are formed at the same time. The food is ingested whole by this enlarged synctia which surrounds and digests it. WILLIER, HYMAN and RIFFENBURGH (1925) have studied the process of intracellular digestion in *Planaria dorotocephala* in great detail. They also failed to find satisfactory evidence of extracellular digestion; certain gland cells in the gut they consider to be reservoirs of reserve food. After feeding animals with beef liver they found that food vacuoles were formed within two minutes, the food being ingested in an amoeboid manner by means of pseudopodia. Digestion of a full meal was completed

within 8 hours. Protein spherules accumulate as digestion proceeds, but these later decrease with a simultaneous increase in the number of fat droplets. There was no evidence of any intermediate formation of carbohydrate, the protein was apparently converted directly into fat. There were no reserves of glycogen in the body.

No work has been done on **Polycladida,** but conditions probably resemble those in the **Tricladida.** In the **Rhabdocoelida** WESTBLAD states that whereas intracellular digestion is apparently exclusively present in the majority, extracellular digestion certainly takes place in members of the Section Hysterophora, with the exception of the family Prorhynchus. In these animals the gut epithelium consists of clearly defined cells which are never amoeboid and never form syncytia, while the lumen of the gut is always large. A digestive secretion is probably poured out together with mucus from the pharyngeal glands. The gut itself contains both gland cells and absorbing cells.

WESTBLAD considers that intracellular digestion is primitive in the **Turbellaria,** the condition in certain of the **Rhabdocoelida** being secondary. In spite of contrary evidence, however, it is very difficult to believe that the Nematodes, Crustacea, Rotifers, and Oligochaetes, which he states are included in their diet, can, withouh aid, be ingested phagocytically. Some preliminary digestion of protein, such as is present in the Coelenterates, appears necessary before the flesh can be ingested by the amoeboid, phagocytic cells of the gut. In certain of the Rhabdocoels, as indicated by the work of WESTBLAD, a definite change in the mode of digestion appears to have taken place. These animals have taken a forward step in evolution, digestion being apparently *exclusively extracellular*, the cells which line the gut being concerned with the absorption of the fluid products of digestion, amino-acids, etc., and not with the phagocytic ingestion of solid particles.

Like the **Coelenterata,** therefore, the **Turbellaria** are as specialized for the digestion of animal prey as they are for its capture.

5. Nemertinea.

Nothing is known of the digestive processes of nemertine worms. They are, apparently without exception, carnivorous.

6. Chaetognatha.

In these animals, also, there is a complete lack of knowledge as to the digestive processes. They are exclusively carnivorous.

7. Rotifera.

The Rotifers are of little significance in the economy of marine life. It is interesting to note, however, that, according to Remane (1929), although intracellular digestion occurs, extracellular digestion preceeds it. Correlated with these two processes are, respectively, the syncytial nature of the gut wall and the paired digestive glands which open into the stomach.

8. Polyzoa.

These animals feed by means of ciliary currents on the tentacles, and their food consists of nannoplankton and is predominantly, therefore, of a vegetable nature. Little is known about their digestive processes, but Cori (1929, 1930) states that in *Pedicellina* digestion is exclusively extracellular. Digestive enzymes are secreted by special cells within the stomach, and are mixed with the food which is entangled in a mucus stream which is drawn through the stomach and rotated by ciliary action. He considers that the major portion of the products of digestion are absorbed in the stomach but that the intestine may assist in this. Roaf (1908) made extracts of entire colonies of *Cellaria fistulosa* and found that these hydrolysed starch and also digested protein in acid media.

9. Brachiopoda.

These animals, also, are ciliary feeders, collecting nannoplankton by means of the elaborate ciliary mechanism on the lophophore. Unlike the **Polyzoa,** however, digestion is certainly primarily, if not exclusively, intracellular. Ashworth (1915) noted the presence of ingested unicellular algae within the cells of the "liver" in larval *Lingula.* More recently the author carried out feeding experiments (the results of which are not yet published) on an Australian species of *Lingula,* and found that when these were fed with the blood of dogfish, the red corpuscles were carried into the lumen of the "liver" and there ingested and digested intracellularly. Nothing is known about extracellular digestion in this phylum; digestion is certainly primarily intracellular.

10. Echinodermata.

From the point of view of feeding and digestion this phylum can be divided into two main groups, the **Asteroidea** and **Ophiuroidea** which are exclusively carnivorous, and the **Echinoidea** and **Holothuroidea** which are primarily herbivorous, although to some extent omnivorous. In addition there are the **Crinoidea** which are ciliary

feeders and so primarily herbivorous, but nothing is known of their digestive processes.

In the **Asteroidea** the animal prey may be swallowed or, if too large, the stomach may be everted over and around it (extra-intestinal digestion). In either case it is broken down by the action of powerful proteases. The origin of these has been disputed. Thus Roaf (1908) obtained a protease which acts in acid and alkaline media and also an amylase from extracts of the pyloric caeca of *Asterias rubens*, but found no enzymes in extracts of the stomach. Van der Hyde (1922, 1923), on the other hand, found a definite digestive action on protein within the excised stomach of *Asterias Forbesii*. A protease was the only enzyme he found free in the lumen of the gut, although in extracts of the stomach and pyloric caeca he found a protease which acted best in alkaline media and an invertase, but no amylase. The products of the initial protein digestion in the stomach are carried into the pyloric caeca by ciliary currents, the nature of which in *Piaster ochraceus* and *Patiria miniata* has been described in detail by Irving (1924). They insure that the food is thoroughly mixed with the digestive enzymes and presented to the extensive absorbing surface. Van der Hyde (1922) and van der Hyde and Oomen (1924) have conclusively shown that absorption takes place exclusively in this region, and that the stomach is concerned only with the secretion of the extracellular protease. They consider that the fine particles of food are taken up by wandering phagocytes, and that the epithelium of the caeca does not absorb, although substances may diffuse through it. This matter, however, requires further investigation. Irving (1926) has demonstrated that the fluid of the pyloric caeca in *Pisaster* and *Patiria* has a ph of 7.6 and that this is maintained by carbon dioxide production. This ph is optimal both for the survival of the cilia in the caeca and for the action of the protease. In *Asterias*, according to van der Hyde, the ph of the stomach-contents varies from 7.1 to 7.7 and that of the pyloric caeca is 7.3.

It is probable that conditions in the **Ophiuroidea** are very similar, but there are few data. Roaf (1908) found in extracts of the disc of *Ophiocoma nigra* sucroclastic enzymes which digested starch, sucrose, lactose and (slightly) glycogen, but not maltose, also a protease which digested fibrin with optimum conditions in $\frac{N}{40}$ HCl, and a lipase.

What is known of the digestive processes of the **Echinoidea** indicates that the enzymes in these more omnivoraus animals are more varied in character. Roaf (1908) made extracts of the intestine (oesophagus and inferior spiral) of *Echinus esculentus* and found that this digested

starch and glycogen readily, maltose less readily and lactose very slowly indeed. He found a doubtful action on sucrose, a protease which had its optimum in acid or alkaline media according to whether it was extracted with water or glycerine respectively, and also a lactose. Van der Hyde (1922) found that *Arbacia punctulata* contained a protease which was free in the gut (extracellular) but was much less powerful than that of *Asterias*. He was also able to find a weak invertase in extracts but not in the digestive fluid, and was unable to find an amylase anywhere! The pH in the gut varied between 7.2 and 7.8. He was able to demonstrate the absorption of fat by the epithelium of the intestine and the possible presence of a lipase in extracts. Phagocytosis may, in his opinion, take place in the epithelium, and not true absorption. The work of Weese (1926) on *Strongylocentrotus drobachiensis* is the only satisfactory paper on digestion in **Echinoidea.** He found that the pH of the digestive tract varies from 6.2 to 6.6, and that extracts of the tissue contain proteases which have optima at pH 2.4 and above 6.6. The former, as he points out, is probably an autolytic enzyme and not concerned with digestion. A powerful amylase was also present which had an optimum at pH 7.5, but he failed to find a lipase.

More recent work has been carried out on the **Holothuroidea** than on the other classes of the **Echinodermata.** Van der Hyde (1922) states that *Thyone briareus* contains a weak protease, acting in alkaline media, free in the lumen of the gut, but he found no other extracellular enzymes, although he found a strong invertase and a weak lipase (but again no amylase!) in extracts of the gut wall. He found the average pH of the stomach to be 7.6, the intestine to vary from 7.2 anteriorly to 7.9 posteriorly, and the rectum 8.2. Oomen (1926) carried out a detailed study of digestion in *Holothuria stellati* and *H. tubulosa.* The pH of the intestine is 5.1 and it contains an extracellular protease, an amylase, an invertase and a lipase, all of them very weak. Extracts of the gut contain powerful enzymes. Starch and sucrose are digested with optimum conditions at pH 6.0, and also glycogen and maltose, but not lactose or raffinose. The strong protease shows increased activity from pH 2.8 to 9.2, with no definite optimum. There is also a relatively powerful lipase.

Oomen (1925, 1926) also found free amoebocytes in the lumen of the gut and in abundance in the epithelium and he considers that these play an important part in the absorption and transport of food. He reinvestigated the properties of the epithelium which had been the subject of a controversy between Cohnheim (1901) and Enriques (1903) and decided that the living epithelium was a semipermeable

membrane incapable of absorbing the soluble products of digestion, and became, after death, a simple diffusion membrane. More recently SCHREIBER (1930) has studied this question yet again and decided that the living gut, under normal conditions, is permeable to glucose. After removal from the body it becomes first semipermeable and then freely permeable in either direction.

As a result of his study of the digestive enzymes of the Japanese holothurian, *Caudina chilensis*, SAWANO (1928) has shown that the intestinal fluid has a pH of between 7.3 and 7.7. There is a lipase and a butyrase in extracts of the tissue, and these may be present in the fluid. An amylase with a pH optimum at 6.3 was identified in both the fluid and in extracts; an invertase was also present in both and a maltase in extracts only, but no enzymes capable of digesting lactose or cellulose. In both extracts and fluid there was a "tryptase" capable of converting fibrin into amino-acids at pH 8. An "ereptase" which converted peptone to amino-acids was found in extracts, but no protease capable of acting in acid media was found. Both extracts and the fluid coagulated milk.

In the **Echinodermata**, although there is an unfortunate lack of authoritative work on their digestive processes, conditions do represent an advance on those in the **Coelenterata** to which they may most suitably be compared. Extracellular digestion is well developed being concerned primarily with protein in the carnivorous **Asteroidea** (and also probably **Ophiuroidea**), and with both protein (though the enzymes are apparently less powerful) and the carbohydrates, starch and sucrose in the omnivorous **Echinoidea** and **Holothuroidea.** In all the digestion of fats is very slow. In all cases the digestion of protein appears to take place with maximum efficiency on the alkaline side of neutrality. In the **Asteroidea** the pyloric caeca are specialized for absorption (or phagocytosis) and in both the **Echinoidea** and **Holothuroidea** there is evidence that absorption may be primarily, if not exclusively, carried out not by the epithelium of the gut but by wandering phagocytic amoebocytes.

11. Mollusca.

From the point of view of feeding and digestion the **Mollusca** are the most interesting phylum in the animal kingdom. Not only do they include within their numbers animals which feed in every possible way, with correlated differences in the relative strengths of their digestive enzymes (and, on occasion, the presence of especial enzymes), but they show every stage between an almost exclusive reliance on intracellular

digestion and extracellular digestion pure and simple. In the **Lamellibranchia** the only extracellular enzymes are those produced by the dissolution in the stomach of the head of the crystalline style, in the **Gastropoda** there is an ever-increasing development of extracellular digestion, while in the **Cephalopoda** extracellular digestion alone is present.

With the exception of the Teredinidae part of whose nourishment is obtained from the wood into which they bore (Potts, 1923, Yonge, 1926a), and the Septibranchia which are carnivorous (Yonge, 1928b), the **Lamellibranchia** are ciliary feeders whose principal food consists of fine phytoplankton. The alimentary canal consists of a short oesophagus, a rounded stomach into which open the ducts of the digestive diverticula (Yonge, 1926a) and into which projects the head of the crystalline style, a mid-gut to which the style-sac may or may not be connected, and a terminal rectum or hind-gut. Material is carried through the gut by ciliary activity defaecation being aided by muscle strands surrounding the rectum. In the Septibranchia alone the oesophagus and stomach possess powerful longitudinal and circular muscles.

There are no "salivary" glands and the digestive diverticula (so-called liver) do not secrete (Yonge, 1926a), the only digestive enzymes present in the gut being those which originate in the crystalline style, and which digest starch and glycogen. This remarkable structure which is found in all **Lamellibranchia** (and also in some **Gastropoda**) consists of a gelatinous rod formed of protein of a globulin nature. It is secreted in a style-sac which may be in communication with the mid-gut (as in *Mytilus* or *Ostrea*) or be entirely separate (as in *Mya* or *Ensis*). The walls of the sac possess very strong cilia the movement of which rotates the style and at the same time drive it forward into the stomach (Nelson, 1918, 1925, Yonge, 1926c). The head af the style bears against a cuticular layer, the gastric shield, on the opposite wall of the stomach to the style-sac. By its revolution it assists in the mixing of food in the stomach and in the drawing in of mucus strings through the oesophagus. At the same time it is dissolved away slowly. This is due to the fact that the globulin of which it is composed is an amphoteric substance which is stable at the low pH (5.4 in *Pecten*, and *Mytilus*, 4.45 in *Mya*, 4.6 in *Ensis*, and 5.2 in *Ostrea*) at which it is produced, but which dissolves readily in the more alkaline fluid of the stomach (Yonge, 1925b, 1926b, 1926c). As a result of its dissolution, not only are the enzymes — which are probably adsorbed on the protein — set free, but the pH of the stomach is lowered to a figure which corresponds very closely to the optimum pH for the action of the enzymes. In animals where the style lies in a se-

parate sac it is always present, but where the sac is in free connection with the mid-gut the style may be absent under certain conditions. If the animal is placed under unfavourable conditions — either in nature or as the result of experiments — the lowering of the metabolism causes a reduction in secretion and the style is dissolved away more rapidly than it is formed. Its presence in animals where the style-sac and mid-gut are in free communication depends on the maintenance of a balance between the rate of its formation in the sac and its dissolution in the stomach (Yonge, 1925b, 1926b, 1926c).

The presence of digestive enzymes in the style was first demonstrated by Coupin (1900) and later confirmed by other workers (see Nelson (1918) for details). Yonge (1923) found an amylase which acted on starch and glycogen, but no other carbohydrate, in the style of *Mya arenaria*, and showed that this enzyme has all the properties of a typical enzyme. More detailed work on the style of *Ostrea edulis* (1926c) revealed that the amylase has an optimum pH at 5.9 and that it is inactivated by purification with absolute alcohol or by dialysis, action being restored on the addition of anions, expecially chlorides and bromides. In *Ostrea circumpicta* Sawano (1929) found that the optimum pH for the activity of the style amylase is 6.0. Graham (1931a) found a similar pH optimum for the style amylase of *Ensis siliqua*, and one of 5.8 for *Pecten maximus* (1931b). He also points out that the apparent temperature optimum for this enzyme varies with the duration of incubation, and that when incubated for the period of time which material takes to pass through the alimentary canal and at a pH approximating to that of the stomach, the optimum temperature is about the natural temperature at which the animal lives. Actually, as will be shown, the effective action of the enzyme is in the stomach and the ducts of the digestive diverticula only, so that this time must be considerably reduced.

In addition to the amylase, the style also contains a complete oxidase system, as shown by Berkeley (1923), Yonge (1926c) and Graham (1931a). Sawano (1929) also states that the style of *Ostrea circumpicta* contains a butyrase and an enzyme which clots milk. Other workers have failed to find such enzymes.

Material carried into the stomach is mixed with the enzymes, largely by the rotation of the style, and at the same time the particles are sorted out by a special sorting mechanism. This was originally described in *Modiolus modiolus* by Nelson (1918) and similar mechanisms have been described in *Mya* (Yonge, 1923), *Ostrea* (Yonge, 1926c) and *Ensis* (Graham, 1931a). As a result of their activity the larger particles are passed into the mid-gut and so to the exterior while the finer ones are

conducted into the ducts of the digestive diverticula into which also pass the soluble products of digestion — namely glucose. In the Septibranchs (YONGE, 1928b) there is no such mechanism the stomach being greatly elongated, highly muscular and entirely covered internally with a thick cuticular lining which appears to be an extension of the gastric shield. The style is very small and of little significance. The small animals swallowed whole are ground to pieces in the stomach which acts purely as a crushing gizzard. In *Tridacna* (unpublished information) there is no sorting mechanism, all particles being conducted into the ducts of the digestive diverticula which, as in the Septibranchs, are exceptionally wide.

The digestive diverticula are organs exclusively of absorption and intracellular digestion (YONGE, 1926a). A circulation is maintained within them by means of long, retractile cilia (POTTS, 1923, YONGE, 1926a), for there is no muscle such as controls a similar circulation in the hepatopancreas of the Decapod Crustacea. Extracts of the diverticula contain a variety of enzymes, e. g. in *Mya* (YONGE, 1923) sucroclastic enzymes acting on starch, glycogen, sucrose, maltose and lactose, a protease acting in acid media and a lipase; in *Ostrea edulis* (YONGE, 1926c) sucroclastic enzymes acting on similar substances and also raffinose and some glucosides, but not on inulin, cellulose or pentosans, a protease and a lipase. The amylase has a pH optimum of 5.5 and is inactivated after purification, action being restored by the addition of the anions, bromides or chlorides. The protease has two optima, one at pH 3.7 and the other above pH 9.0 and its action is very slow. In *Ostrea circumpicta* SAWANO (1929) found that the protease had two optima, at pH 4.0 and 8.5 when casein was the substrate, and at 4.1 and 8.5 when gelatine was used. In *Ensis* (GRAHAM, 1931a) the protease has optima at pH 4.2 and 8.2.

In addition to the absorption of glucose and the intracellular ingestion of fine particles (e. g. Indian ink (VONK, 1924) or iron saccharate (YONGE, 1926a, 1926c)) by the cells of the digestive diverticula, an additional source of digestive activity is provided by the presence of great numbers of wandering phagocytes which pass through the walls of the gut, especially in the stomach, mid-gut and ducts of the digestive diverticula, engulf food in the lumen, and then pass back through the epithelium (YONGE, 1926a, 1926c). By this means edible particles too large to enter the digestive diverticula and, owing to their nature, incapable of being digested by the enzyme from the style, are assimilated by the animal. Both diatoms and blood corpuscles from fish on which the animals were experimentally fed were taken in by these phagocytes and digested.

It is notable that in the Septibranchs where the food does not consist of fine particles, these wandering phagocytes are completely absent (YONGE, 1928b).

In the wood-boring Teredinidae there are interesting modifications of the alimentary system. There is an elongated blind sac opening into the posterior end of the stomach which is always filled with the fine fragments of wood scraped off by the modified shell valves which form the boring organ. More important is the presence of a modified region of the digestive diverticula consisting of wider and more thin walled tubules than those of the normal portion from which it can be distinguished at sight by its lighter colour. This region is specialized for the intracellular digestion of wood (SIGERFOOS, 1908, POTTS, 1923, YONGE, 1926a). A cellulase which converts cellulose into glucose has been extracted from this region by HARRINGTON (1921), DORE and MILLER (1923) and BOYNTON and MILLER (1927).

It has been suggested, notably by RANSON (1924, 1925, 1926, 1927) that the **Lamellibranchia** absorb soluble matter directly through the epithelium of the gills, palps, mantle, and other exposed surfaces. The author in the various papers quoted above failed to find the absorption of colloidal iron saccharate other than in the digestive diverticula and very occasionally in phagocytes. As a result of experiments on *Ostrea edulis* (YONGE, 1928c) it was shown that whereas glucose is removed from solution in sea water by normal animals, it is not removed when the mouths are plugged. On the other hand, if the plugged animals are kept until, as a result of these abnormal conditions, they begin to "bleed" (i. e. phagocytes begin to be extruded in large numbers into the mantle cavity) then glucose is removed. These results have been confirmed by KOLLER (1930) working on *Mytilus edulis* and *Mya arenaria* and estimating the occurrence or otherwise of absorption by the difference in oxygen consumption after glucose was added to the water containing the animals.

The **Lamellibranchia** are, therefore, specialized herbivores capable of the extracellular digestion only of starch or glycogen. Minute fragments of protein or fatty material are ingested and digested intracellularly by the cells of the digestive diverticula, and rather larger particles by the wandering phagocytes. Small copepods may pass through the alimentary canal and emerge alive at the anus (this frequently happens to the oyster larvae) owing to the absence of a protease in the gut. The absence of such an enzyme is essential if a style be present (YONGE, 1930a) for the globulin of which it is composed is readily digested by any protease. *The presence of a style indicates that its possessor is a spe-*

cialized herbivore. The exception to this rule is provided by the Septibranchia, but in these the style is vestigial while the animal matter on which they feed is *not digested extracellularly* but is broken into fine fragments and forced into the digestive diverticula, which are exceptionally wide, and there ingested and digested intracellularly. They are the only carnivorous Mollusca which do not possess an extracellular protease. In common with all other **Lamellibranchia** they possess a single extracellular enzyme capable of digesting starch and glycogen only.

In the **Gastropoda** every type of feeding mechanism is found, and the different genera may be herbivorous, carnivorous or omnivorous with correlated variations in the nature and relative strengths of the different digestive enzymes. The mode of digestion varies from conditions similar to those found in the **Lamellibranchia** to the exclusive development of extracellular digestion characteristic of the **Cephalopoda.**

It will be most convenient here to discuss first the herbivorous genera (excluding the **Pulmonata**) and then the carnivores. The former may conveniently be divided into two groups, those which possess and those which do not possess a crystalline style. This organ is particularly common in the simpler **Streptoneura,** notably in the ciliary feeders such as *Crepidula* (Mackintosh, 1925), *Vermetus* (Yonge, 1931b), or *Turitella* (Yonge, unpublished observations), but it is also present in the Thecasomatous Pteropods (Meisenheimer (1905), Yonge, 1926d). The style is also found in a number of Gastropods which feed by means of a radula, many of these are freshwater species (see Robson, (1922), Mackintosh (1925) and Yonge (1931b) for full details) but is occasionally found in marine genera such as *Patella* and *Pterocera.* In the latter case it is remarkably well developed attaining a length of 10.5 cm. and lying in a separate style-sac (Yonge, 1931b).

In all of these Gastropods the conditions of digestion are essentially similar to those in the Lamellibranchs. Although "salivary" glands are usually present they are in all cases small and it is doubtful whether they secrete anything other than mucus. The style contains an amylolytic enzyme as shown for *Crepidula* by Mackintosh (1925) and for *Pterocera* by Yonge (1931b). In *Crepidula* where the style-sac is in free communication with the mid-gut, the style dissolves away under unfavourable conditions (Yonge, 1925b) for the same reason as for the styles of the Lamellibranchs which it also resembles in being the cause of the acidity (about pH 6.0) of the stomach. The presence of a style indicates the absence of any extracellular protease, which has been experimentally demonstrated in the case of *Pterocera* (Yonge, 1930a, 1931b). These

Gastropods differ from the Lamellibranchs in the absence of wandering phagocytes in the gut. The ducts of the digestive diverticula (which in no case probably secrete) are, however, very wide and permit the entrance of comparatively large particles and there is no rigorous sorting of particles in the stomach. *Pterocera* is of especial interest in that the stomach contents contain a powerful cellulase which acts rapidly upon cellulose with a pH optimum at 5.1 (Yonge, 1931b). The origin of this enzyme could not be determined.

Herbivorous **Gastropoda** without styles include Tectibranchs such as *Aplysia* and Nudibranchs such as *Caliphylla* and *Hermaea*. The former feeds exclusively on *Ulva* and, as shown by Enriques (1901) and Bottazzi (1901) there is no evidence of absorption elsewhere than in the cells of the gastric gland certain of which have definite phagocytic powers while others are secretory. They also found that the living foregut is impermeable to salts. The fluid in the stomach contains an amylase, a cellulase and a protease and is very acid (Enriques). The crop has the exceptionally low pH of 4.5 and the stomach of between 5.2 and 5.6 (Yonge, 1925b). The enzymes are secreted either by the salivary glands or the secretory cells of the gastric gland or, most probably, by both. *Caliphylla* and *Hermaea* feed on algae such as *Bryopsis* or *Codium* and, according to von Bruel (1904), the fluid protoplasm is sucked into the gut and passes in the diverticula which possess muscles whose action maintains an active movement in and out of them. The green chloroplasts are ingested and digested intracellularly by the absorbing cells of the diverticula.

The carnivorous **Gastropoda** are characterized by the presence of powerful extracellular proteases some or all of which may be produced by large "salivary" glands. In *Sycotypus canaliculatus* Mendel and Bradley (1905) found that the "salivary" glands secrete a "ropy mucin-laden solution containing a proteolytic enzyme" with properties closely resembling those of trypsin. Extracts of the "liver" contained only amylase, invertase and lipase. Roaf (1906) on the other hand found a protease which acted in acid media on fibrin in extracts of the "liver" of *Fusus antiquus*. Hirsch (1914) has studied the digestive processes of a number of carnivorous marine Gastropods, *Natica hebracea*, *Murex trunculus*, *Pterotractea mutica* and *Pleurobranchae meckelii*. All of these possess powerful proteases produced by the gastric gland, with the exception of *Natica* where the large "salivary" gland is probably alone respon sible for it.

Amylase and glycogenase were also found in all, again, with the exception of *Murex* where they are secreted by the large "salivary"

glands, in the gastric gland. A lipase was also present in all cases in the latter organ. Animals such as *Pleurobranchaea* and *Pterotrachea* which feed by swallowing large animals — in contradistinction to the other animals studied which "rasp" their food by means of a radula before swallowing it — possess a large crop in which the food lies while it is being broken down by the proteases. In Tectibranchs such as *Scaphander* and *Bulla* this process is taken a stage further by the presence of a crushing gizzard. A very important point established by Hirsch's work is that secretion of enzymes in these Gastropods is invariably *rhythmical*, both in the "salivary" and gastric glands.

In a later paper (1924) Hirsch has studied absorption in *Murex*. He has shown that soluble or coiloidal matter (e. g. iron saccharate) is assimilated in the "salivary" glands and by the absorptive cells of the gastric gland, whereas solid particles (if less than 25 μ in diameter) may be ingested phagocytically in the latter. The red blood corpuscles of fish have been observed ingested in a similar manner by the cells of the gastric gland in *Doris* and in various Gymnosomatous Pteropods (Yonge, unpublished work). In these latter cases there is free and wide communication between the interior of the gland and the stomach. The hydrogen ion concentration in the gut of *Buccinum* and *Doris* has been examined by Yonge (1925b), in both cases the stomach contents are on the acid side of neutrality (5.6 and 5.7 respectively). As shown by Semon (1889) and earlier workers a variety of carnivorous Gastropods, such as *Dolium*, *Cassis*, *Cassidaria*, *Tritonium* and *Pleurobranchaea*, possess free sulphuric acid in the secretion of the "salivary" glands. This apparently assists in the breaking down of the calcareous shells of the prey.

A great deal of important work has been carried out on the terrestrial and freshwater **Pulmonata** which can only briefly be referred to here. Peczenik (1925) has shown that intracellular digestion takes place in the "liver" of *Limnea*, but, in spite of the contrary findings of Jordan (1918), this has been denied for *Helix* by Krijgsman (1925, 1928). According to him digestion is entirely or almost entirely extracellular in *Helix*, and the production of enzymes by the "salivary" and gastric glands is rhythmical. The salivary glands secrete sucroclastic enzymes, notably an amylase and probably a cellulase which is present in quantity in the fluid of the crop but which has never been identified in extracts of either gland. This cellulase has been investigated by many workers, most recently by Karrer and co-workers in a series of papers. The ph optimum lies at about 5.3. Enzymes breaking down chitin and lichenin have also been identified by these workers. Krijgsman (1928) has de-

monstrated that a lipase is secreted by the gastric gland which also produces calcium phosphate which may control the pH of the gut. No protease has ever been identified in the gut and only in very small amounts in extracts of the gastric gland, and KRIJGSMAN suggests that only soluble proteins may be taken in and then digestion completed within the absorbing cells of the gastric gland — if this is so then digestion is *not* exclusively extracellular. JORDAN and LAM (1918) have shown that the gut in *Helix* does not absorb but is a diffusion membrane which will even allow disaccharides (JORDAN and BEGEMANN, 1921) to pass through. Absorption takes place exclusively in the gastric gland.

In **Gastropoda** therefore, although conditions may closely resemble those in the **Lamellibranchia,** as in *Crepidula* where there is a style and there are digestive diverticula which absorb and digest intracellularly but do not secrete, yet in carnivorous genera such as *Murex* or *Doris* the diverticula secrete and so may be termed a gastric gland, although they also possess cells which absorb and digest intracellularly. Secretion of extracellular enzymes is assisted by "salivary" glands. In Pulmonates, such as *Helix*, there is no phagocytosis of fine particles by the gastric gland although the intracellular digestion of soluble proteins or proteoses may take place. The specialization of enzymes is well illustrated by the presence of cellulase in herbivorous genera so widely separated systematically as *Pterocera*, *Aplysia* and *Helix*, and by the special development of powerful extracellular proteases in carnivorous genera such as *Natica* and *Murex*, and their complete absence in herbivorous genera which possess a style and also in *Helix*.

In the **Cephalopoda** digestion is exclusively extracellular. The Octopods possess two pairs of salivary glands, the posterior pair of which is alone present in some Decapods, such as *Sepia*. The anterior pair apparently secrete only mucus. The posterior pair secrete mucus, a poison allied to tyramine (HENZE, 1905, 1913, 1929) while the presence of a protease acting in acid media has been reported by KRAUSE (1895, 1897) and FALLOISE (1906). It has been supposed that the poison assists in the destruction of the prey, and the protease in its preliminary digestion external to the body of the Cephalopod, but the recent work of SERENI (1929) has shown that the glands secrete into the blood stream and that the tyramine is necessary for the maintenance of the life of the animal. It is doubtful, therefore, whether they are of any significance in digestion. The secretion of digestive enzymes takes place probably in the "liver" and in the "pancreas", both of which apparently possess secreting cells which are absent from the rest of the gut. A number of authors have identified digestive enzymes in the stomach fluids, notably a lipase and a

powerful protease which quickly breaks down proteins to amino-acids. Extracts of the "liver" and "pancreas" doubtfully contain an amylase but there is a powerful glycogenase though no other sucroclastic enzyme. (For details of the authorship of this work, all of which is old, see Jordan, 1913).

Enriques (1901) has shown that fat may be absorbed by the epithelium of the stomach and of the caecum which opens into it, and Lohnheim (1902) that amino-acids may be absorbed by the intestine. According to some authors absorption also takes place in the "liver" but this has been disputed.

Although there is an unfortunate lack of recent work on the digestive processes of the **Cephalopoda,** it is yet clear that digestion is exclusively extracellular and that the digestive enzymes are those of a typical carnivore, a powerful protease being the most conspicuous while glycogen is the only carbohydrate which can be digested with ease (or at all).

12. Annelida.

In spite of the size and great importance of this phylum, very little is known about the digestive processes of its members. Such work as has been done confirms the impression gained by an examination of the histology of the gut, that (like the **Polyzoa**) digestion is *exclusively extracellular*. The **Polychaeta** (which will be exclusively considered here) comprise animals which feed in almost every conceivable manner, carnivores like *Nereis*, herbivores like *Cirratulus*, and ciliary feeders like *Sabella*. Brand (1927) has studied their feeding habits in some detail and also pointed out the important fact that, with a few exceptions, the glycogen content of the ciliary feeders and other herbivores is much higher than that of the carnivores.

The secretion of enzymes may occur in the walls of the intestine, as in *Sabella pavonina* (Nicol, 1930) or in diverticula such as the oesophageal caeca of *Nereis* (Dorman, 1928) or the numerous gut diverticula of *Aphrodite aculeata* (Jordan, 1904a). Very little is known about the enzymes secreted. A variety of early workers (see Jordan, 1913) found a protease acting in alkaline media in extracts. Brasil (1903) found that extracts of the intestinal caeca of *Arenicola* digested fibrin in alkaline media, but not starch. In *Lagis korenii* he found (1904) an amylase in the descending arm of the intestinal loop with traces of a lipase, and in the ascending arm a protease acting in alkaline media. Nicol (1930) found that in the ciliary feeder, *Sabella pavonina*, whose food is principally phytoplankton, there are sucroclastic enzymes which digest starch,

glycogen and the glucoside, salicin, but not sucrose, maltose, lactose, cellulose or pentosans. Starch and glycogen were digested most rapidly at pH 6.8. There was a protease with a pH optimum at 7.8, and a lipase with an optimum at 7.4. The pH of the gut was about 6.8 anteriorly rising to 8.0 or even 8.4 at about the hundredth segment, behind this it falls suddenly to pH 7.0 and then more slowly to 6.0. According to Brasil (1904) absorption takes place to a greater or less extent throughout the surface of the entire gut in *Lagis korenni*. Jordan (1904a), on the other hand, found by careful experimentation that in *Aphrodite aculeata* absorption takes place *exclusively* in the numerous diverticula where the absorbing cells are mingled with the secreting cells.

13. Crustacea.

The **Crustacea** (like all **Arthropoda** with the exception of certain blood-sucking **Aracnida**) resemble the **Annelida** in the complete absence of intracellular digestion. The alimentary canal in the **Crustacea** consists typically of three portions, a fore- and a hind-gut, both of which are lined with chitin, and a mid-gut which alone is not chitinised. Diverticula are usually present at the junction between the fore-gut and mid-gut. In the **Copepoda** and other **Entomostraca** there is on the dorsal side, a single median caecum which extends anteriorly into the head region, this becomes a more complex series of four long tubules, extending posteriorly through the greater part of the length of the body in the **Isopoda** or **Amphipoda**, while in the **Decapoda** it takes the form of the elaborate mass of ramifying and anastomosing tubules known as the hepatopancreas. The secretion of digestive enzymes takes place exclusively in these tubules where, as in the **Isopoda, Amphipoda, Decapoda** and other more complex **Crustacea**, they are well developed. In the **Entomostraca** the caeca, where present, secrete, but the anterior region of the mid-gut also produces enzymes.

These digestive enzymes are passed forward into the fore-gut where they are mixed with the food. In the **Entomostraca**, which are almost exclusively filter feeders, straining out finely divided particles — largely phytoplankton (see Dakin (1908) and Esterley (1916) on the food of **Copepoda**) — from the water by means of special setous mechanisms, this region of the gut is not very elaborate. In the higher **Crustacea**, however, it becomes a very elaborate organ. Its structure has been described in detail for the **Amphipoda** and **Isopoda** by Ide (1892), for the **Schizopoda** by Gelderd (1906) and for the **De-**

capoda by Mocquard (1884). The function of this complicated "stomach" has received less attention than it deserves. Jordan (1909) has studied the stomachs of *Nebalia*, *Idothea* and *Gammarus*, Rehorst (1914) that of *Asellus aquaticus*, while that of the **Decapoda** has been examined in detail by several workers, notably Jordan (1904b) on *Astacus*, Williams (1907) on *Homarus* and Yonge (1924) on *Nephrops*. In the simpler **Malacostraca**, where the food — of a mixed nature but largely vegetable matter — is masticated before it is swallowed, the stomach is concerned essentially with the effective mixing of the food with the enzymes from the tubules of the hepatopancreas. The two openings of this gland are guarded by a delicate filter, and the secretion is carried forward into the "stomach" in special channels. After digestion has been completed, the fluid containing the soluble products of digestion flows into the mid-gut, and also probably to some extent into the hepatopancreas. Murlin (1902) found that in a variety of land **Isopods** absorption took place in the gut, and this is certainly the principal site of absorption in the lower **Malacostraca.** In the **Decapoda** conditions are different. Here the food in swallowed is large pieces and mastication takes place in the stomach. Unlike the other **Crustacea** considered above, there is a powerful armature of three calcified teeth. These are situated in the anterior or "cardiac" portion of the foregut and are worked by special gastric muscles the action of which causes them alternatively to be drawn apart and then driven together with considerable force. The calcified limbs of other crustaceans can quickly be reduced to small fragments in this gastric mill. Posterior to the large, sac-shaped "cardiac" fore-gut, is the smaller "pyloric" fore-gut, from which it is separated by a cardio-pyloric valve. There are three channels connecting the two regions of the stomach, one on either side of the base of the valve and one above it. The latter allows fine particles to pass posteriorly between a "press" consisting of muscular pads the action of which forces these particles into the mid-gut, which is usually found full of dry indigestable fragments which are carried through the mid-gut and hind-gut by peristaltic action. The secretion from the hepatopancreas passes into the stomach by way of the two lateral channels at the base of the cardio-pyloric valve. Digestion takes place within the "cardiac" fore-gut and the fluid-products of digestion are carried back in the same channels into the "pyloric" region. The openings of the hepatopancreas are situated ventrally on either side of the posterior end of this region and are guarded by a most elaborate filter. This consists of two chitinous plates each curved in a semicircle and uniting in the middle line to form a ridge. Each of these bears numerous transverse chitinous

rods which possess rows of fine setae on their inner sides. The whole forms a most efficient filter, allowing the secretion from the hepatopancreas to pass out through it and also the soluble products of digestion, but not any fine particles, which might block the narrow tubules of the hepatopancreas, to pass inwards.

In the **Decapoda** not only does the secretion of digestive enzymes take place *exclusively* within ferment cells within the tubules of the hepatopancreas, but the absorption of the soluble products of digestion takes place principally in this region. Absorption does take place in the mid-gut and in short anterior and posterior appendages from it (see Yonge, 1924), but the absorbing surface is negligible compared with that presented by the very numerous, ramifying tubules of the hepatopancreas. The greater part of the cells of the tubules are absorptive cells, and their function has been demonstrated experimentally by Jordan (1904 b) and Yonge (1924) for *Astacus* and *Nephrops* respectively. Since secretion is forced out of the hepatopancreas and the soluble products of digestion are drawn into it some mechanism is necessary for the rhythmical contraction and expansion of the tubules. This is provided by a complicated series of longitutinal and transverse muscle fibres which lie embedded in the tunica propria which surrounds the tubules, details of which have been given by Pump (1914), for a variety of **Malacostraca** and Yonge (1924) for *Nephrops*. Moreover Hirsch and Jacobs (1928, 1930) have demonstrated the presence in *Astacus* of a rhythmical secretion of enzymes by the secreting cells of the hepatopancreas. The hepatopancreas of the **Decapoda** is thus a most important organ, providing all digestive enzymes, the great bulk of the absorptive surface, and being in addition an important storage organ especially for the glycogen used in the formation of new chitin after each moult.

In the **Stomatopoda**, as Petricevic (1915) has shown for *Squilla mantis*, the structure and function of the gut is essentially similar. Unlike the **Decapoda**, however, which are omnivorous, being principally scavengers, the **Stomatopoda** are exclusively carnivorous feeding on living animal prey which their great activity and specialized mouth parts enable them to obtain.

Little is known of the digestive enzymes of the **Entomostraca.** Van Dehn (1930) has shown by feeding experiments that *Daphnia* can digest protein, fat and starch, but not cellulose or pectin. Patané (1928) states that the "pancreatic" gland of *Balanus perforatus* contains amylase, invertase and lipase, but he failed to identify any protease! In the **Isopoda**, Murlin (1902) as a result of observations on what

they absorbed found that the secretion of the hepatopancreas digests proteins, carbohydrates and fats. Yonge (1927) found that, though extracts of large numbers of *Limnoria lignorum* would digest starch quickly, they failed to digest cellulose, although this animal invariably lives in timber and its stomach always contains great quantities of wood. Willer (1922) has shown that *Gammarus pulex* (**Amphipod**) can digest proteins, fats and starch, while the extract also coagulates milk.

Although recently much exact work has been done on the digestive enzymes of the fresh-water crayfish, *Astacus*, comparatively little is known of the enzymes of the marine Decapods. Roaf (1908) found that extracts of the hepatopancreas of *Cancer pagurus* digested starch, glycogen and maltose readily, and also sucrose and lactose but more slowly. Fibrin was digested best in alkaline media $\left(\frac{N}{20}\ Na_2CO_3\right)$, and a lipase was also present. Giaja (1909) made an extensive survey of the enzymes capable of digesting carbohydrates and glucosides is a variety of marine Decapods. Sellier (1910) examined the proteases of *Cancer* and *Maja*. Yonge (1924) found that extracts of the hepatopancreas of *Nephrops norvegicus* digested starch, glycogen, sucrose, maltose and lactose but not raffinose, inulin or cellulose. A lipase was present which acted on a variety of esters as well as on neutral fats. The powerful protease had its optimum in alkaline media. Verwey (1930) states that the stomach contents of the mangrove crab, *Thalassina anomala* have a ph of 5.1 in a hungry animal and contain a protease which acts in alkaline media, a lipase, an amylase and an invertase. Mansour-Bek (1930) has studied the proteolytic enzymes contained in extracts of the hepatopancreas of *Maja squinado* using the adsorption methods of Willstätter to separate the various enzymes. By this means it was shown that there are a number of different proteases such as Willstätter and his co-workers have shown to exist in the Vertebrates. There is a proteinase acting on casein or gelatine with ph optima at 6.0 and 6.1 respectively in the ordinary extract, but of 7.4 and 8.1 when they have been purified. Unlike the unpurified extract, the purified extract is activated with enterokinase wherein it resembles vertebrate trypsin. Other proteases identified consisted of a carboxypolypeptidase acting on Chloracetyltyrosin, an aminopolypeptidase acting on leucyldiglycin and a dipeptidase acting on glycylglycin.

In view of the important work done on *Astacus* and the close resemblence of the digestive processes of this animal to those of the marine Decapods, mention must be made of the chief papers on its digestive enzymes. Shinoda (1928) states that the ph of the fluid in the stomach is 5.1 in a hungry animal and 5.6 after feeding. He found in this fluid

a "pepsin" (recognized by its action on connective tissue) with a pH optimum at 6.8, and other proteases acting on a variety of proteins and on peptone with pH optima between 5.3 and 9. He found little trace of an erepsin acting on dipeptides but identified an autolytic enzyme with two optima at 3.5 and 9. KRÜGER and GRAETZ (1927a, 1928) and KRÜGER (1929) on the other hand believe there is an erepsin with an optimum at pH 9, and failed to find any autolytic enzymes. KRÜGER and GRAETZ (1927b) have worked on the lipase in the stomach fluid and find it has an optimum pH of 5.7. WIERSMA and VAN DER VEEN (1928) found a powerful amylase, a very weak invertase and a maltase with pH optima at 5.6, 5.7—6.0, and 5—6 respectively, but no lactase. KRÜGER (1929) states that the maltase has a pH optimum of 5.3.

In the **Stomatopoda,** PETRICEVIC (1915) states that extracts of the hepatopancreas of *Squilla mantis* contain enzymes capable of digesting proteins, peptone and fats but *not* carbohydrates (although glycogen is stored in the hepatopancreas).

In addition to the universal exclusive presence of extracellular digestion in the **Crustacea,** there is an interesting development in the specialization of the hepatopancreas as the only site of secretion and practically exclusive site of absorption. Exactly the same specialization has taken place in *Aphrodite* in the **Annelida** (JORDAN, 1904a), and SELLIER (1910) has also pointed out the resemblence between the digestive enzymes of the marine **Decapoda** and *Aphrodite.* The omnivorous habit of the **Amphipoda, Isopoda** and **Decapoda** is reflected in the presence in them of powerful proteases, lipases and carbohydrate-splitting enzymes. On the other hand the herbivorous **Cirripedia** apparently digest protein with difficulty (they must, in spite of PATANÉ's negative findings, digest it in some degree) while the exclusively carnivorous **Stomatopoda** cannot apparently digest carbohydrates at all.

14. Tunicata.

These animals are all ciliary feeders, their principal food being phytoplankton. The gut is lined with cilia by the action of which food is transported. Digestion is exclusively extracellular. In *Ciona intestinalis* (YONGE, 1925a) secretory cells are present in the epithelium of the stomach, but in *Tethyum pyriforme americanum* and *Boltenia ovifera* (BERRILL, 1929) there is a "liver" which is primarily an organ of secretion. The fluid in the gut of these last two animals has a pH round about 7.0. In *Ciona* starch, glycogen and sucrose are digested but not maltose, lacrose, cellulose, raffinose or inulin. There is also a lipase and an ex-

tremely weak protease acting in neutral and slightly alkaline media. In *Tethyum* there is a powerful amylase, an invertase, a maltase, a lactase, a protease and a very weak lipase. The amylase, which is many times stronger than the protease, has an activity range of pH 6.0 to 8.5 with an optimum about 7.5, while the protease is active from pH 6.0 to above pH 10.0, with an optimum between 8.0 and 8.5. The lower the temperature the slower that food passes through the gut, and also the lower will be the effective optimum temperature of the enzymes which are two-thirds to three-quarters destroyed during their period of activity. Absorption takes place in *Ciona* primarily in the mid-gut, to a smaller extent in the stomach but only to a slight degree in the hind-gut. A notable feature in the epithelium of the mid-gut and to a less extent of the stomach is the presence of large, round or elliptical cells which contain large deposits of glycogen.

In spite, therefore, of the resemblence of their feeding mechanisms and food to those of the **Brachiopoda** and **Lamellibranchia**, the **Tunicata** justify their high place in the animal kingdom by the complete absence of intracellular digestion. In the relative strengths of their enzymes they closely resemble the **Lamellibranchia** owing to the herbivorous habit common to both, and this is also reflected in the large deposits of glycogen.

15. Pisces.

Digestion in the **Pisces** is essentially the same as in other **Vertebrata.** Protein, fat and carbohydrates are digested by extracellular enzymes exclusively. The digestive system in fish is, however, somewhat more primitive than in the higher vertebrates. Salivary glands never occur in fish, and their absence is clearly correlated with the fact that fish never chew their food, they bite or crush it and then swallow it immediately. The pancreas is never so well developed as in the higher vertebrates, and is, indeed, absent in many **Teleostei** where its place is apparently taken by the pyloric caeca which open into the gut at the junction of the stomach and the duodenum. As will be discussed in more detail shortly, certain **Teleostei** have no stomach and the digestion of protein is modified in consequence of the lack of the pepsin and hydrochloric acid glands which are invariably present in the stomach mucosa. In other respects digestion in the **Pisces** is very similar to that in the **Mammalia.**

Full references to early work on digestion in **Pisces** is given by Biederman (1910) and only recent work of especial interest is summarized here.

In the **Elasmobranchii,** it has been shown by Bodansky and Rose (1922b) that in *Squalus acanthias*, *Pristis pectinatus*, and *Torpedo galvani* pepsin can be extracted from the gastric mucosa which has an optimum at pH 3.0 and digests fibrin most readily in a medium of 0.2 % HCl. Of the three only *Torpedo* contains a rennetic enzyme. Vonk (1927, 1929) found that in *Acanthias* the stomach contents have a pH of 2.8 and that the pepsin has an optimum at pH 2.2—2.5. van Slyke and White (1911) studied the digestion of protein in the stomach and intestine of a dogfish (species not given) and found that it takes from 2 to 3 days for a full meal to be digested — some six times longer than in a warm blooded Mammal. In *Acanthias* Vonk states that the pancreas contains an amylase and a maltase with optimum pH at 6.0—6.5 and 6.0—7.5 respectively. As in other Vertebrates the pancreas contained a trypsinogen and the intestine an enterokinase and an erepsin. The trypsin had a optimum pH of 8.2 and the erepsin one of 8.7. The pancreatic secretions of the skates, *Raja erinacea*, *R. diaphanes* and *R. stabuliforis* have recently been carefully examined by Babkin (1929). The secretion is neutral (pH 6.6—7.2) and contains protease, amylase and lipase. The same enzymes were found in alcoholic extracts of the pancreas, the protrypsin being activated by extracts of the mucous membrane of the duodenum or spiral valve made in 0.9 % NaCl. Pancreatic secretion is continuous but scanty in starving animals but can be increased by HCl and secretin, while the introduction into the duodenum of the acid digest of proteins increased this effect in the case of HCl.

In the **Teleosteii,** Bodansky and Rose (1922b) found that *Lutjanus aya*, *Paralichthys lethostigma*, *Laclophrys tricornis* and *Mycteroperca bonaci* all possess a pepsin which digests gelatine with most readiness at pH 3.0 and, with the exception of the last, also a gastric rennin. Extracts of the pyloric caeca of *Lutjanus* contain trypsin, pepsin, rennin, amylopsin, a weak lipase and a very weak invertase, but no inulase, maltase or lactase. This corresponds roughly to the contents of the pancreatic secretion and the secretion of the stomach combined in the higher vertebrates. Vonk (1927, 1929) who worked on two freshwater fish, *Cyprinus* and *Esox*, which possess no pyloric caeca found very similar conditions to those recorded by him for *Acanthias*, with the one exception that the pH of the stomach was 5.2 instead of 2.8.

Babkin and Bowie (1928) in their work on the digestive system of *Fundulus heteroclitus* have pointed out that Teleosts can be divided into two groups according to whether or no they possess a stomach. *Fundulus* does *not* possess a stomach. This is proved by the complete absence of pepsin and HCl in the digestive juices, by the fact that all

digestion takes place in alkaline media and that the duodenum is joined directly to the oesophagus. In consequence of this the bile and pancreatic juice flows into the gut a few millimetres below the oesophagus while the duodenum can dilate for the reception of food. An amylase, a lipase and an erepsin were found in extracts of the mucous membrane of the intestine which probably also contains an enterokinase. The contents of the gall bladder included a trysinogen (protrypsin), a prolipase and an active amylase. This they suspected to originate in the layer of pancreatic tissue which surrounds the gall bladder, a fact which has since been proved by MacKay (1929b). The same author (1929a) has studied the digestive system of *Zoarces anguillaris* which possesses a true anatomical stomach (though no pyloric caeca) the reaction of which is always near neutrality, between pH 6.5 and 8.4, so that, although it was possible to extract a weak pepsin-like enzyme from the gastric mucosa with a pH optimum near 1.2, it appears impossible that pepsin can play any important part in the digestion of proteins in this fish. Lipases were extracted from the gastric mucosa, the duodenum and the liver and an amylase from the two former, much more powerful in the duodenum. The fluid of the stomach and of the duodenum contained a powerful protease with an optimum pH near neutrality in addition to the other enzymes. This could only originate in the pancreas which opens by a common bile and pancreatic duct into the duodenum.

Dawes (1929) has recently studied the histology of the gut in *Pleuronectes platessa*. He finds that the pyloric caeca have the same histological structure as the intestine with which they are in free communication, and he therefore concludes that they have the same function of absorption and secretion. He has later shown (1930) that fat is absorbed in both the stomach and the intestine (including the duodenum). The rectum is capable of a small amount of absorption. Although fat is absorbed principally in the stomach when the fish is fed after a period of starvation, if the frequency of meals is increased the intestine and duodenum become the principal sites of absorption.

16. Discussion.

This short survey of digestive processes brings out very clearly the gradual development of extracellular digestion with the increase in the complexity of the organism. Whereas digestion is exclusively intracellular in the **Protozoa** (with a very few exceptions) and the **Porifera**, it is accompanied by extracellular digestion to a greater or less degree in the **Coelenterata**, **Turbellaria** (possibly in all, certainly

in some), **Rotifera, Brachiopoda, Echinodermata,** and **Mollusca** (with the exception of the **Cephalopoda**). Digestion is entirely extracellular in the **Polyzoa, Annelida, Crustacea, Tunicata** and **Pisces.**

Intracellular digestion demands finely divided food particles and a very extensive surface for its assimilation. The former may be obtained either by the sieving action of the feeding mechanisms, as in the **Porifera, Rotifera, Brachiopoda,** probably the **Crinoidea, Lamellibranchia** and ciliary feeding **Gastropoda,** or by the reduction of the food by the action of extracellular enzymes. Thus in the **Coelenterata,** possibly in the **Turbellaria,, Asteroidea** (and **Ophiuroidea**) and in the carnivorous **Gastropoda** the prey is broken down by powerful extracellular proteases. In the **Lamellibranchia** and in herbivorous **Gastropoda** there is an extracellular digestion of starch and, in the latter, sometimes of cellulose. The great extent of the assimilating surface is exemplified by the flagellated chambers of the **Porifera,** the mesenterial filaments of the **Anthozoa,** the ramifying gut of the **Tricladida** and **Polycladida,** the pyloric caeca of the **Asteroidea,** the digestive diverticula of the **Lamellibranchia** and certain primitive **Gastropoda** and the gastric gland of the higher **Gastropoda.** In the **Lamellibranchia** which are the most highly organized animals which depend primarily on intracellular digestion, the digestive diverticula are assisted by the wandering phagocytes which are everywhere abundant in the gut.

Undoubtedly the point of greatest practical importance is the specialization of digestive enzymes. It is clearly useless to expect an animal to obtain nourishment from material which it cannot digest owing to lack of the necessary enzymes. The **Coelenterata** and **Turbellaria,** for example, possess no extracellular amylase and are probably incapable of digesting any carbohydrate other than glycogen intracellularly. They are highly specialized carnivores. In both the **Asteroidea** and the **Cephalopoda** conditions are very similar. In these animals and also in the Scyphozoan *Rhizostoma* the prey is broken down outside the body by means of extruded proteases (for details of this "extra-intestinal" digestion see Jordan (1910) and Lengerken (1924)). In contradistinction to the omnivorous **Decapoda,** the **Stomatopoda** are specialized carnivores apparently incapable of digesting starch or sucrose. The **Lamellibranchia** and style-bearing **Gastropoda** are the most specialized of herbivores. The very presence of a style indicates that there is no extracellular protease and that all protein must be

ingested in the form of fine particles by the cells of the digestive diverticula. The Septibranchs are the exception which proves this rule, although carnivores they possess no extracellular protease. On the other hand starch is digested readily by the enzyme from the style. A protease is also absent from the gut fluids of *Helix* where, as in the style-bearing *Pterocera*, there is an extracellular cellulase as well as an amylase. The **Cirripedia** also appear to be specialized herbivores.

The **Tunicata**, although capable of digesting protein, certainly break down carbohydrates with much greater efficiency. Other animals, such as the **Echinoidea** and **Holothuroidea**, probably the **Polyzoa**, the majority of **Annelida** and the **Decapoda**, are definitely omnivorous digesting proteins, fats and carbohydrates with equal ease.

In certain cases the animal only swallows the kind of food it can digest. For example the majority of predacious carnivores will refuse to feed on anything but animal prey. But in other cases, notably ciliary feeders, animals which swallow bottom material and **Entomostraca** which feed automatically by means of setous appendages, there is *no* selection except of size of particles. The only way of determining what proportion of the stomach contents which a Lamellibranch, a Holothurian or a Copepod can utilize is by a study of its digestive enzymes. For example, in spite of the large proportion of detritus taken into the stomach of oysters and other Lamellibranchs, they are incapable of utilizing it owing to their inability to digest either cellulose or pentosans. Again, the wood-boring Teridinidae can utilize the carbohydrates in the wood owing to their possession of an intracellular cellulase, but the wood-boring *Limnoria* and *Chelura*, although their stomachs are always full of wood fragments, cannot utilize this because they do not possess a cellulase.

It has been suggested that bacteria may play a part in digestion in marine invertebrates as they do in herbivorous mammals. Although little work has been done on this subject, nothing that is known supports this view. In the case of the **Lamellibranchia** where it has been advanced most frequently it is inherently improbably because the bacteria would undoubtedly be ingested by the cells of the digestive diverticula or by the wandering phagocytes. They would form ideal food for the animal and would never be able to multiply in the gut.

Symbiosis with unicellular algae undoubtedly plays an important part in the nutrition of certain marine invertebrates, notably in the Turbellarian, *Convoluta*. On the other hand the presence of zooxanthellae in **Madreporaria** (and other **Anthozoa**, possibly in all **Coelen-**

terata) is of no assistance in nutrition although the association is probably of great value to the animal owing to the automatic removal of excretory products (Yonge & Nicholls, 1931 a, 1931 b).

There is no space here to discuss Pütter's theory that marine invertebrates obtain a large proportion of their food from the direct assimilation of soluble matter. Nevertheless at the conclusion of a survey such as this it is not inappropriate to stress the evidence to the contrary presented by the great efficiency and high degree of specialization possessed by the feeding mechanisms and digestive processes of marine invertebrates and fishes.

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Observations on the Phosphate-Content and Hydrogen-Ion Concentration of the North Sea, the Southern Entrance to the Norwegian Sea, and the Water South of Iceland.

By

H. R. Seiwell.

1. Introduction.

The phosphate and hydrogen-ion analyses on which the principal part of this paper is based were made by the author on board the yacht Carnegie while en route from Hamburg, Germany, to Reykjavik, Iceland, July 1928.

The material has been placed at the disposal of the author by Mr. John A. Fleming, Acting Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

Appreciation is expressed to Captain J. P. Ault, Commander of the Carnegie, and his navigating assistants for determining the positions of the observing stations, as well as to other members of the scientific staff of the Carnegie who gave assistance to the author in various ways.

2. Positions of Observing Stations.

(Plate I.)

The North Sea stations (July 8th to 11th, 1928) extended in an almost straight line from near the mouth of the Elbe River, station 1, to the vicinity of the Shetland Islands, station 15.

Stations 16 to 22 (July 11th and 12th) were on an almost direct line stretching between the northeast extremities of the Shetland and Faero Islands, thus crossing the eastern part of the Faero—Shetland Channel. Of this latter group of stations No. 17 was over the steep southeast bank of the Channel; Nos. 18 and 19 were over the deepest part of the Channel; and No. 20 was over the steep northeast bank.

Stations 24 to 29 (July 13th and 14th) were located over the Faero—Iceland Ridge. At station 26 observations extended from surface to bottom.

Stations 30 to 37 (July 15th to 19th) were located at distances varying from fifteen to seventy-five miles off the south coast of Iceland, the average was about forty miles. The depth of water ranged from 150 meters close inshore to 2,000 meters farthest from the coast. At station 31 a vertical series of observations was obtained from surface to bottom.

The bathymetric positions of the stations have been determined both from HELLAND-HANSEN and NANSEN's bathymetric chart of the Norwegian Sea (1, plate I), and from soundings taken by the Carnegie (2).

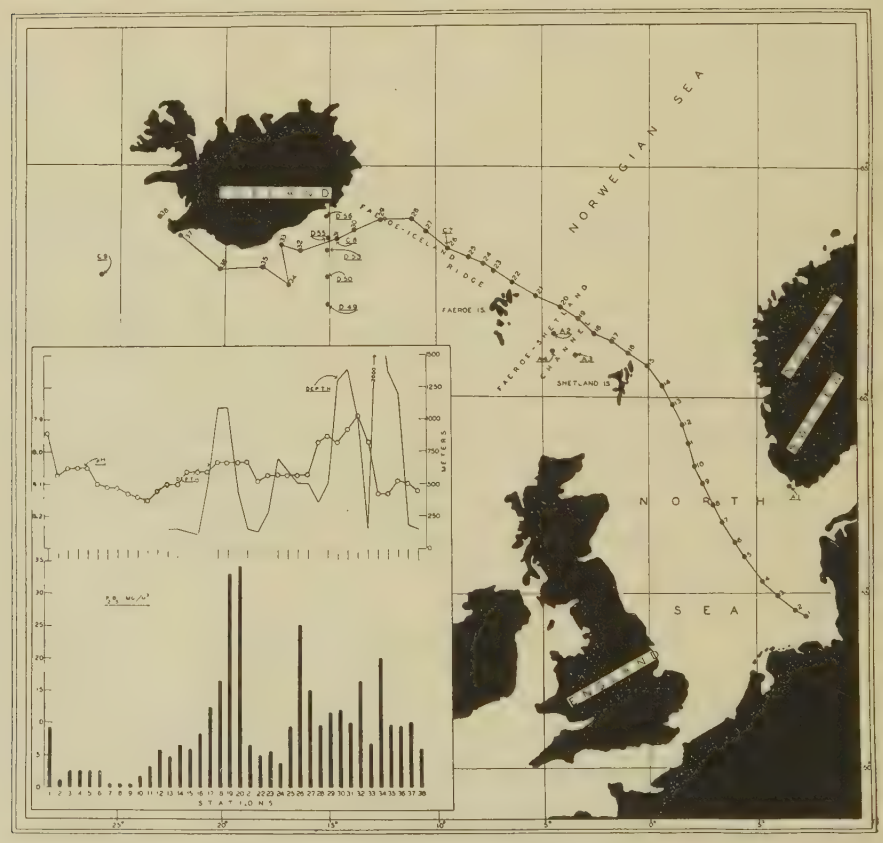

Plate I — Observing stations of the Carnegie between Hamburg, Germany and Reykjavik, Iceland, and other stations mentioned in this paper.
Inset — Surface phosphate-content, pH, and depth at »Carnegie« stations.

3. Phosphate in the Surface-Water of the North Sea, July 8th to 11th, 1928.

All phosphate estimations were made by means of the coeruleo-molybdate colorimetric method of Denigès (3), using Nessler color comparison tubes more than 100 centimeters long, the bottoms of which had been replaced by colorless polished glass discs.

Stations 1 to 11, inclusive, have been considered as being in the main part of the North Sea. Reference to plate I will indicate that the surface-waters of this area were almost exhausted of phosphate, and with the exception of station 1, which may have a higher surface-content because of proximity to the mouth of the Elbe River, the P_2O_5 content ranged from 0.6 to 3.1 milligrams per cubic meter. Near the north center of the North Sea (stations 7, 8, and 9) the surface-water had practically reached a state of complete phosphate exhaustion.

This low phosphate-content of the surface-water is in accordance with the results obtained two to three weeks earlier in the season by the author while working in the southern part of the North Sea. The average P_2O_5 content of the surface-water for a mean latitude of 52°34′ North was then found to be 3.44 milligrams per cubic meter (4).

Atkins, from the results of investigations in the North Sea has concluded that the seasonal changes in the phosphate of the water were very similar to those taking place in the English Channel, the minimum values occurring in July and early August. The almost complete utilization of phosphate from surface to bottom is indicated by analyses on July 8th, 1922, near the center of the North Sea, when Atkins recorded 3 milligrams per cubic meter of P_2O_5 for the surface water and 5 milligrams per cubic meter for the bottom water at a depth of fifty meters (3).

In the deep water off Norway, however, Atkins has pointed out that an analysis of the water on August 30th, 1924, latitude 57°51′ North longitude 6°39′ East (station A1 on chart, plate I) indicates that the deeper layers have not been denuded of phosphate as those of the same depth have at station E1 in the English Channel. This he assumes to be due to the fact that there is less mixing of the epithalassa with the hypothalassa (3).

In summarizing the temperature-observations of the North Sea, Knudsen and Gehrke (5) have shown that in summer the region north of Dogger Bank (about latitude 54° North), depth considerably less than one hundred meters, there is an average temperature-difference surface to bottom of 7° to 8°. To the south of Dogger Bank the water column has at all times of the year nearly the same temperature surface to bottom.

As most of our observations were north of Dogger Bank, the surface values obtained do not necessarily give any indication of the amount of phosphate present in the deeper layers for photosynthetic activity, as surface observations would in the water to the south of Dogger Bank. However, as the depth of water in the North Sea is generally less than one hundred meters, we should expect in summer to find the phosphate to be more or less utilized throughout the whole column. In the deeper water of Norway, where the depth may extend below the limits of plant activity, and where the surface-layers are warmer than they are in the center of the sea, there is considerably more resistance to vertical mixing and phosphate may then accumulate in the deeper layers.

The phosphate-content of the surface-water lying between stations 11 and 15, near the Shetland Islands, increased to 5—6 milligrams P_2O_5 per cubic meter. This enrichment may be the result of an influx of richer Atlantic water flowing to the south of the Shetlands.

4. Phosphate in the Surface-Water lying between the Faero and Shetland Islands, July 11th and 12th, 1928.

Perhaps the most striking thing about the surface phosphate-values (plate I) obtained for this series of stations is the enormous quantities recorded at stations 19 and 20 (32.8 and 33.8 mg/m³ P_2O_5). The surface phosphate-content increased continuously from station 15 (5.8 mg/m³) south of the Shetland Islands, to reach its maximum at station 20, and then to drop sharply again at stations 21 (6.5 mg/m³) and 22 (4.9 mg/m³) on the Faero Bank.

Thus, the phosphate-content of the surface-water between the Shetland and Faero Islands was greatest at the east central and northeast part of the Faero-Shetland Channel.

The hydrographical observations of Helland-Hansen and Nansen (1) in this region have shown that the main part of the Norwegian Atlantic Current enters the southern part of the Faero-Shetland Channel, and running toward the northeast or to some extent east, it generally keeps close to the Shetland Bank. A smaller volume of water enters the northern part of the Channel and running towards the south or southeast it joins the main body of the current.

Between the Shetland and Faero Islands it has been shown (6) that the surface-water is largely Atlantic water while the bottom-water is Norwegian Sea water. Between the Atlantic water and bottom-water there exists an intermediate layer formed by the mixing of Atlantic water with bottom-water and water introduced from the East Icelandic

Arctic Current. The characteristic mixings of the layers are met with especially in the shallower parts of the area in question, out to a depth of 200 meters, but also out in the middle of the channel there is a zone where mixing is very pronounced owing to eddy formation in connection with the strong currents.

Helland-Hansen and Nansen (1) have pointed out that the Arctic water is brought by the East Iceland Arctic Current along the northern slope of the Faero-Iceland Ridge into contact with the Atlantic Current already in the northern mouth of the Faero-Shetland Channel. By numerous great and small horizontal vortices (with vertical axes) formed during the northward course of the Atlantic Current, its waters are continually more and more intermixed with those of the Arctic Current. A study of temperature- and salinity-sections across the Channel shows the occurrence of numerous vertical vortex movements (with horizontal axes) which cause a considerable intermixture with underlying bottom-water, and a similar intermixture with underlying bottom-water is also produced by horizontal vortex movements.

It thus appears as if the very high phosphate-content of the surface-water in the Faero-Shetland Channel might be due principally to the mixing of surface with deeper rich phosphate water resulting from the vertical and horizontal vortex movements of the water. For purposes of illustration Helland-Hansen and Nansen's chart of circulation of the Norwegian Sea (1, fig. 2, page 9) is helpful.

In this same season, July 6th, 1925, Atkins (7) recorded values of 30 and 23 milligrams P_2O_5 per cubic meter for the surface-water at two stations in the Faero-Shetland Channel (stations A2 and A3, plate I). Also on August 5th, 1924, this same author (3) recorded a value of 74 milligrams P_2O_5 per cubic meter for the surface-water to the north of Scotland (station A4, plate I). The accuracy of these analyses of Atkins may be somewhat impaired due to storage of the samples for several weeks before analyses, but the magnitude of the results lend evidence that high surface phosphate-content as well as perhaps other nutrient materials may prevail in the surface-waters of the Faero-Shetland Channel throughout the summer months.

5. Phosphate in the Surface-Water over the Faero-Iceland Ridge, July 13th and 14th, 1928.

Stations 24 to 29 were over the Faero-Iceland Ridge stretching between the Faero Islands and Iceland, and forming a fairly level plateau at depths ranging between 400 and 500 meters. Some parts of the ridge

rise above 400 meters and near the Faero Islands the depths are frequently greater than 500 meters.

The opening between the Faero Islands and Iceland, like the Faero-Shetland Channel, forms one of the gateways through which the Atlantic Current streams into the Norwegian Sea. The conditions existing on each side of the ridge are sharply contrasted, to the south the salinities and temperatures being very high as compared with conditions north of the ridge. A sharp boundary between warm salt Atlantic water and colder more diluted waters moving southwards along the eastern coast of Iceland is always found near Vestre Horn.

Vertical mixing, no doubt, occurs on the ridge owing to eddy formation resulting from the currents and enriches the surface-layers with nutrient materials brought up from the deeper water. The phosphate-content of the water over the ridge (stations 24 to 29) ranged from 3.8 to 25 milligrams per cubic meter, higher values were recorded over the central

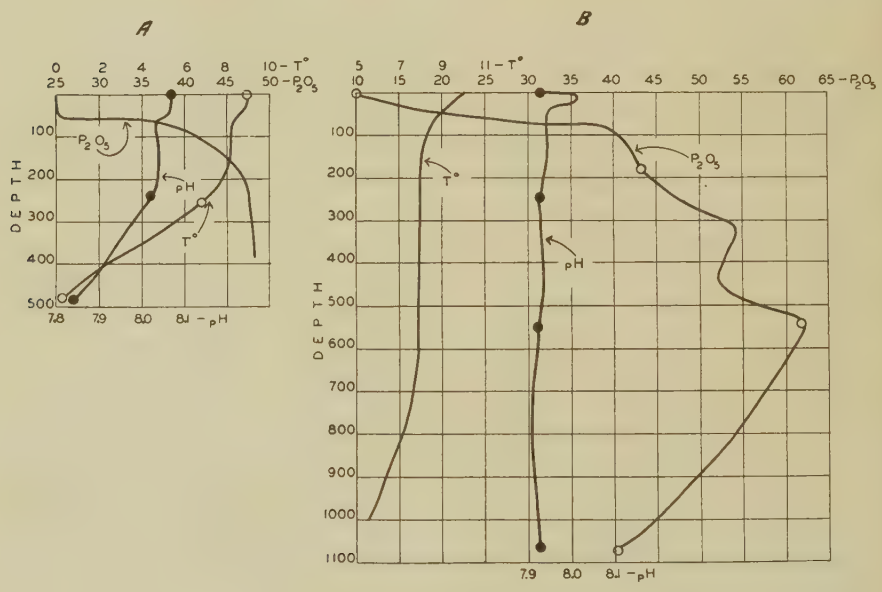

Plate II — A, vertical distribution of phosphate, pH, and temperature at station 26 (Carnegie station 7); and B, vertical distribution of phosphate, pH, and temperature at station 31 (Carnegie station 8).

and northern part of the ridge. The average phosphate-content of the surface-water over the ridge (12.3 mg/m³ P_2O_5) was about one half of that recorded for the surface-water of the Faero-Shetland Channel.

The vertical distribution of the temperature[1]) and phosphate at station 26 (Carnegie station 7) near the centre of the ridge is illustrated in plate II. The temperature of the upper two hundred meters was almost uniform, range 8°.92 to 7°.81, below the two hundred meter level the gradient increased, the temperature decreasing to 0°.31 at 483 meters. The phosphate in the water mass varied from 25 mg/m³ at the surface to 48 mg/m³ at 400 meters. In the lower portion of the water column, between 200 and 400 meters, the phosphate-content was practically uniform.

At the time of the year our observations were taken, photosynthetic activity in this locality should be close to its maximum and consequently the phosphate-content of the layers available for plant activity should be at a minimum, unless phosphate as well as other manurial substances, are continually being brought up from the deeper water through circulation of the water mass. The relatively large amount of phosphate present in the upper 200 meters at station 26 would seem to indicate that vertical circulation plays an important part in keeping the upper layers supplied with phosphate.

As an index of the resistance of the water mass to vertical mixing near the central part of the Faero-Iceland Ridge, we have from the specific volume calculations of Ault[2]) computed the state of the vertical stability. The stability of the water mass has been computed after the method suggested by Sandstrøm (8) by determining the number of isosteric surfaces per ten meters depth, and is graphically illustrated by a vertical line the thickness of which has been drawn proportionate to the stability. The state of the vertical at station 26 (Carnegie station 7) is represented in plate III. The water mass tends toward a more or less uniform stability and nowhere in the vertical column is there a stable layer developed which would offer a great resistance to vertical stirring.

6. Phosphate in the Surface-Water South of Iceland, July 15th to 19th, 1928.

The phosphate-content of the surface-water fifteen to seventy five miles off the south coast of Iceland (stations 30 to 37) ranged 6 to 20 milligrams P_2O_5 per cubic meter; in general the phosphate-content of the surface-water was highest where the water is deep and farthest from shore.

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[1]) Temperature observations and calculations by J. P. Ault, Commander of yacht Carnegie.

[2]) Specific volume calculations at Carnegie stations 7, 8, and 9 by J. P. Ault.

The vertical distribution of phosphate and temperature at station 31 (Carnegie station 8) is graphically represented in plate II. Similar to station 26 the phosphate-gradient is greatest in the upper 100-meter layer, the values recorded for the 100-meter level were the same at both stations. Below 100 meters the phosphate increased to more than 60 milligrams per cubic meter at 550 meters depth and then decreased to 40 milligrams per cubic meter at 1066 meters depth. An apparent dif-

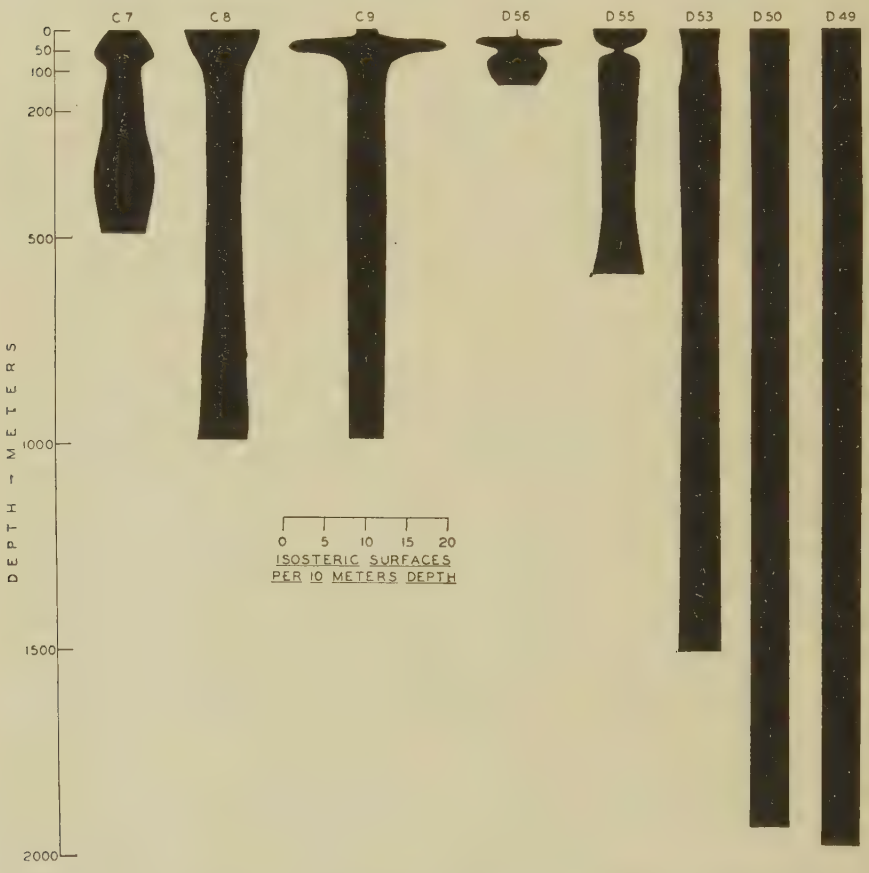

Plate III — Stability of water around Iceland. For positions of indicated stations see plate I.

ference exists between stations 26 and 31 in the phosphate-content below 200 meters. In the former case we have seen it was practically uniform and in the latter it increased with depth showing the deeper water to be richer in phosphate.

The vertical temperature-gradient at station 31 is more uniform

than at station 26; there is no influx of cold water above 500 meters as in the latter case where the temperature at 483 meters was almost 0°.

The vertical state of stability at station 31 has been determined by the same method used for station 26, and is graphically illustrated in plate III. The most stable part of the vertical occurs in the upper 100-meter layer, in lower levels the stability decreased in linear proportion to depth. The upper 100-meter layer of station 31 was somewhat more stable than that layer at station 26, and this difference in stability may partially account for the difference in the phosphate-content of the surface-water between station 26 (25 mg/m³) and station 31 (10 mg/m³). The phosphate-content at 100 meters is almost the same at both stations (40 mg/m³).

As a provisional test of the stability of the water mass to the south of Iceland, in relation to distance from shore, we have calculated the specific volume and hence the stability from the temperature- and salinity-data obtained by the Danish investigators in this region in May 1896 (9). The Danish stations selected for stability computation lay on a straight line about 100 miles east of stations 32 and 34, extending from 15 to 110 miles off shore (D stations, plate I). The results are graphically illustrated in plate III, and indicate that the most stable verticals at this season of the year exist in the shallower water close to the coast (station D 56). In the deeper off-shore water (stations D49, D50 and D53) the water mass was of constant stability.

7. General Conclusions of the Distribution of Phosphate in the Area Investigated.

It would appear from plate II, as well as the foregoing discussion, that observations on the phosphate-content of the surface-water do not always give a true indication of the amount of this material available for photosynthetic processes. We have seen that at stations 26 and 31, where the surface phosphate-content was 25 and 10 milligrams per cubic meter, respectively, that at one hundred meters approximately 40 milligrams per cubic meter was recorded for each station. This was also the case at Carnegie station 9 in the open Atlantic (plate I, station C9) where 15 milligrams per cubic meter P_2O_5 were recorded for the surface-water and 41 milligrams per cubic meter for the 100-meter level (10). Similar results have been obtained by the author in tropical waters of the North Atlantic, where surface-waters were almost exhausted of phosphate (3.5 to 5 mg/m³ P_2O_5), yet at one hundred meters there were quantities ranging from 41 to 90 milligrams P_2O_5 per cubic meter (10).

Quite obviously, inorganic phosphate, as well as other nutrient materials, in the off-shore surface-layers depend to a great extent on the amount of mixing with the rich subjacent layers and the intensity of this vertical mixing is indicated by the stability of the water. In the area investigated the factors affecting vertical stability are principally changes in the density of the water column resulting from temperature and salinity alterations (principally the former) and eddy formation resulting from strong currents. Evidence seems to point to vertical mixing in the Faero-Shetland Channel and on the Faero-Iceland Ridge as principally the result of smaller vortex movements of the water, while that in the sea south of Iceland may be principally the result of convection currents resulting from changes in the density of the water.

In the sea south of Iceland it has been shown by Nansen (11) that between Rockall Bank and Iceland the density increases in a northerly direction due to slowly decreased temperature of the surface-water in the same direction. Cooling of the ocean's surface results in producing convection currents in the sea south of Iceland which may extend to a depth of nearly 800 meters, there being a great uniformity of temperature and salinity in this region between 100 and 800 meters resulting from this circulation. The effect of vertical circulation in the upper one hundred meters is less marked in July on account of solar warming.

Solar warming of a surface-layer of variable thickness increases resistance to vertical circulation and may produce a marked effect on the phosphate-content of the surface-water. In regions where there is a sufficiently strong cyclonic vortex motion, the deeper water may be brought close to the surface and the warm layer may be quite thin, but in the absence of this vortex motion, the warm stable layer may extend to various depths, and in the shallow water over the banks the warm layer may reach from surface to bottom.

The uniform condition of the column of water over the northeast part of the Faero Bank and the northern part of the Shetland bank as compared with the deeper water farther off-shore has been illustrated by Nansen (11, tafel XVI). The water over these banks is of almost uniform salinity and temperature, while farther off-shore cyclonic vortex movements bring up colder deeper water closer to the surface. As the bank-water is shallower than the surrounding water, during summer it is heated to a higher temperature and becomes lighter than surrounding water at the same levels. Thus, an interchange of water between it and the deeper layers is inhibited. As the phosphate is utilized in the water over the banks in summer and additional material is not forthcoming from the richer deeper waters to replenish the supply, we should expect

that it would eventually become greatly reduced or even exhausted (stations 15, 21, 22, etc.).

On the other hand in the surface-layers of the deeper water, eddy movements resulting from the velocity of currents produce a mixing of the surface and subjacent layers which will tend to enrich the surface-layers with phosphate and other nutrient materials (stations 18, 19, 20, etc.).

In contrast to the summer conditions of water over the banks, it has been shown by NANSEN (11) that since the layer of bank-water is thinner than in the deep sea, cooling during the winter must make the water colder and consequently heavier than in the surrounding deeper regions. This bank-water, now instead of being warmer than the surrounding water is colder and heavier and it will sink down along the sides of the bank to a position of equilibrium and be gradually replaced by water from the sides. The importance of this winter circulation in restoring the bank-water with phosphate and other nutrient materials from the deeper layers is evident.

The greater part of the North Sea covered by our investigations was in practically all cases sufficiently shallow (100 meters or less) so that photosynthetic activity could extend throughout the whole column of water. As a result of this it is quite probable that over the greater part of the shallow North Sea, phosphate is more or less utilized from surface to bottom during the summer months in spite of the existence of an appreciable thermocline during this season. This condition is corroborated by results of ATKINS in the North Sea; exceptions as in the deeper water off the coast of Norway have been noted.

8. The Method Employed in the Estimation of the Hydrogen-Ion Concentration.

The hydrogen-ion concentration, reported in terms of the Sørensen unit, pH, was determined colorimetrically by means of a double wedge comparator such as described by BARNETT and BARNETT (12) and MOBERG (13). The apparatus used in this investigation was carefully checked at a temperature of 26° against La Motte standardized buffer mixtures at the beginning of the investigation in Hamburg, Germany, and at the end in Reykjavik, Iceland. The indicator used was cresol red, and the results have been corrected for salt-error after RAMAGE and MILLER (14), these authors give a correction of —0.27 unit of pH to be applied for salinities lying between 32 and 35 ‰.

The pH determinations on surface-samples were always made im-

mediately after collection of the sample, the temperature of the indicator-solutions in the wedge being the same temperature as the sample at the time of collection. For the measurement of pH on samples obtained in a depth series, as at stations 26 and 31, the temperature of the indicator-solutions in the wedge as well as that of the samples were all adjusted to the temperature of the surface-water. The pH-values used in the discussion have only been corrected for salt-error, other possible corrections are discussed elsewhere.

9. Hydrogen-Ion Concentration of the Region Investigated.

The hydrogen-ion concentration, corrected for salt-error, increased from pH 7.94 at station 1 in the southern part of the North Sea, near the mouth of the Elbe River, to pH 8.15 at station 11 in the north central part of the North Sea. In the vicinity of the Shetland Islands (stations 15, 16 and 17), the pH dropped to 8.06, while in the Faero-Shetland Channel, the pH was still lower, 8.03, rising to 8.09 in the shallow water over the Faero bank (station 22).

Over the southern half of the Faero-Iceland Ridge the pH was consistently 8.07, but considerably lower values were encountered over the northern part of the ridge and in the water to the south east of Iceland (pH 7.89 to 7.97). The pH of the water to the southwest of Iceland ranged 8.09 to 8.13.

In a general way the variation of the surface hydrogen-ion concentration is coincident with the differences in circulation existing in the region. The most alkaline water was found in the northern parts of the North Sea, while the most acid was over the northern part of the Faero-Iceland Ridge and the adjoining water southeast of Iceland. In this latter area the low pH may be partially due to the mixing of the colder water brought down by the East Icelandic Arctic current with the warmer water of the Atlantic. Similarly, the pH was lower in the surface of the strongly mixed Faero-Shetland Channel than in the surrounding surface bankwater.

Photosynthesis at this time of the year, no doubt, tends to increase the pH, but in areas of strong vertical circulation where the surface-layers are mixed with the water from the lower levels as in the Faero-Shetland Channel or on the Faero Iceland Ridge this effect would tend to be offset by the replacement of surface-water by the more acid water from the lower levels.

The vertical distribution of hydrogen-ion concentration, corrected for salt-error, at station 26 (Carnegie station 7) is illustrated in plate II.

The maximum variation from surface to bottom at 483 meters, pH 8.08 to 7.84, is greater than the surface variation on the Faero-Iceland Ridge, pH 7.95 to 8.07.

Similarly we have in plate II the vertical distribution of pH, corrected for salt-error, for station 31 (Carnegie station 8). With the exception of the surface-layers, the gradient is more uniform than at station 26. The measurements recorded for surface and bottom are identical, being almost the minimum value found for the whole vertical column. The maximum variation of pH, corrected for salt-error, (7.91 to 8.02) is less than was recorded for the shallower column of water at station 26 on the Faero-Iceland Ridge and also less than the variation of surface pH south of Iceland (7.89 to 8.13).

Because of different methods and standards used by many investigators for the determination of pH in sea-water, as well as the various salt-error corrections applied to these determinations, it is not always possible to compare results obtained in pH investigations of the sea. It appears, however, from an examination of the results of other investigations that the surface pH of cold northern waters is lower than that of the warmer surface waters of more southern latitudes. Thus, the author on board the Carnegie, using the same method as in the investigation under discussion, found that during the months of July to September the pH of surface-water was generally higher in the southern parts of the North Atlantic than in the more northern parts[1]). Palitzsch (15), during the Thor expedition (1911—1912) made pH determinations on fresh samples of sea-water and found for the surface-waters of the western end of the Baltic, the Skagerak and south of the North Sea the pH was between 8.00 and 8.05, and farther south off the coast of Portugal it had risen to 8.25. This same investigator also found that off the Scotland and Faero Islands the pH varied 8.08 to 8.22, while in the Mediterranean it was usually above 8.22.

Measurements given by Nansen for Spitsbergen waters (15) obtained July and August 1912, during the cruise of the Veslemoy, were mostly low. Using Palitzsch's mixtures this investigator found that in the cold salt-water, 4°.8 to 0°.55, the values generally lay between pH 7.94 to 8.08, but some remarkably high values, pH 8.19 to 8.25, are also given. With the higher values the gradient of change with depth is steeper than in the warmer seas.

The hydrogen-ion results obtained by Thompson and his coworkers

[1]) Unpublished data on hydrogen-ion concentration of North Atlantic obtained during cruise of Carnegie.

at the Puget Sound Biological Station, and by Moberg at Scripps Institution of Oceanography are more comparable to those obtained by the author. These investigators have both used the Barnett type of wedge-comparator, and a comparison of their results seems to indicate that the pH was in general lower in the colder water of higher latitudes. Johnson and Thompson (16) report that during July and August 1928 at the Puget Sound Biological Station, the hydrogen-ion concentration of the surface-water, uncorrected for salt-error, ranged 7.9 to 8.5 units of pH. The average temperature of the surface-water during this period was 10.9°. Moberg (17) working in the La Jolla region, records an average surface pH, corrected for salt-error (—0.27 unit of pH added to results), for the summer of 1926 of about 8.20 for a station ten miles off shore. The average surface-temperature during this period at the ten-mile station was about 20°.

As the observations under discussion were obtained close to mid-summer, we should expect, because of conditions of phytoplankton production, and temperature of the surface-water, that the pH readings obtained were close to the maximum for the year, although not necessarily the maximum. Atkins (18) working in the English Channel found that in a general way the pH maximum could be correlated with the diatom maximum in early summer and autumn.

In the Puget Sound region, Johnson and Thompson (16) found that the pH throughout the year (September 1927 to September 1928) remained practically constant, pH 7.8 to 7.9, uncorrected for salt-error, except during the latter part of July and the month of August when there was considerable fluctuation, pH 7.9 to 8.5. Moberg (13) also found that in the La Jolla region over a period of four years the pH was higher in summer than in winter. This latter investigator calls attention to the fact that weekly means at the Scripps Institution pier for the period 1922 to 1925, inclusive, indicate that there may be a considerable difference between different years; the pH and temperature maxima and minima not always being synchronous.

10. The Possible Effect of Temperature on Colorimetric Measurements of Hydrogen-Ion Concentration of Sea-Water.

In the discussion of the method of observing pH, we have seen that the double wedge comparator was calibrated at a temperature of 26°, while the temperature at which it was used for pH determinations in the field was, in this investigation, considerably lower — namely, the temperature of the surface-water. In general, the temperature at which

the observations were made ranged from 8°.9 to 14° or 17° to 12° lower than the temperature at which the wedge comparator was colorimetrically calibrated.

K. Buch (19, 20), from the result of a study of the influence of temperature on the dissociation constants of various indicators when admixed with borax buffer solutions and with sea-water, has concluded that temperature plays a complex role in the accurate colorimetric estimation of pH, and is something which should not be neglected. This investigator, by making spectrophotometric investigations of the absorption of light by various indicators in both buffer solutions and sea water at varying temperatures, experimentally determined two constants, α indicating the amount by which the dissociation exponent of the indicator varies for a temperature change of one degree in the borax buffer solutions, and β, for the color-change of the indicator taking place in sea-water (salinity 34.5 ‰) with changing temperatures.

In the case of cresol red, α, or the alteration of pK per degree in borax buffer mixtures, was calculated by Buch to have a mean value of 0.0053 (negative as pK declines with rising temperature), and β, or the average amount by which the pH value declines per degree with rising temperature as indicated by the color-change of cresol red, was calculated to have a mean value of 0.006 unit of pH.

On the theoretical assumption that the indicators studied were weak acids which become ionized on the addition of a base, the ion differing in colour from the undissociated acid, Buch applied the mass action law and deduced a simple formula for the calculation of pH at the time of collection from the colorimetric estimation, provided certain other measurements were taken. The pH and temperature of the water in situ has been designated by pH_{tw} and t_w; the pH and temperature of the comparison standard as pH_{tb} and t_b. The pH of the water in situ can then be calculated by means of the equation:

$$pH_{tw} = pH_{tb} + \alpha\,(t_b - t_w).$$

When the temperature of the sample is several degrees higher at the time of measurement —′ (t'_w) than at the time of collection (t_w), the correction $\beta\,(t'_w - t_w)$ should be added to the above equation.

In accordance with the theory put forward by Buch (20), and on the basis of the assumption that the pK-value of the cresol-red indicator coloring the solutions in the wedge was altered because of the lower temperature at which the measurements were made in the field, we have in column 9, table 1, tabulated the pH of the surface-water when corrected for this temperature-effect. Similarly in column 6, table 2, are

Table 1.

Station	Latitude North	Longitude	Date 1928	G.M.T. h m	T °C	P_2O_5 mg/m³	pH*	pH**	Salinity ‰
1	54°21′.9	7°19′.4 E	July 8	16 06	13.6	9.3	7.94	8.00	33.12
2	54 32 .6	6 54 .6 E	— 8	20 44	14.0	1.1	8.07	8.13	..
3	54 51 .1	6 02 .0 E	— 9	2 21	..	2.5	8.05	8.12	..
4	55 17 .7	5 17 .8 E	— 9	8 31	12.2	2.5	8.05	8.12	34.38
5	55 56 .7	4 28 .0 E	— 9	18 25	12.0	2.5	8.05	8.12	..
6	56 19 .5	4 06 .2 E	— 9	21 40	12.0	2.5	8.10	8.17	..
7	56 48 .5	3 37 .7 E	— 10	1 45	..	0.6	8.11	8.18	..
8	57 18 .3	3 07 .1 E	— 10	5 45	..	0.6	8.11	8.18	34.87
9	57 49 .3	2 36 .5 E	— 10	10 30	11.8	0.6	8.13	8.20	..
10	58 21 .3	2 08 .1 E	— 10	14 55	11.6	1.7	8.14	8.21	..
11	58 50 .4	1 48 .2 E	— 10	19 15	11.0	3.1	8.15	8.23	35.03
12	59 21 .3	1 28 .1 E	— 11	1 40	11.0	5.7	8.12	8.20	..
13	59 48 .1	1 06 .9 E	— 11	6 03	..	4.8	8.10	8.18	..
14	60 17 .8	0 39 .4 E	— 11	10 00	10.8	6.5	8.10	8.18	..
15	60 43 .1	0 05 .4 W	— 11	14 40	10.9	5.8	8.06	8.14	35.35
16	61 04 .6	0 56 .5 W	— 11	19 30	10.6	8.2	8.06	8.14	..
17	61 20 .3	1 43 .0 W	— 11	22 51	10.2	12.3	8.06	8.14	..
18	61 34 .9	2 33 .3 W	— 12	2 00	..	16.4	8.03	8.11	..
19	61 51 .2	3 17 .2 W	— 12	6 00	9.5	32.8	8.03	8.11	..
20	62 04 .7	4 08 .4 W	— 12	9 23	9.6	33.8	8.03	8.11	35.26
21	62 20 .3	5 21 .0 W	— 12	13 28	9.6	6.5	8.03	8.11	..
22	62 35 .8	6 25 .3 W	— 12	17 18	9.2	4.9	8.09	8.18	..
23	62 51 .7	7 16 .5 W	— 12	22 48	9.1	5.4	8.07	8.16	..
24	63 00 .0	7 50 .2 W	— 13	2 23	..	3.7	8.07	8.16	..
25	63 08 .3	8 34 .0 W	— 13	7 18	9.5	9.3	8.07	8.16	..
26	63 20 .5	9 25 .4 W	— 13	14 44	8.9	25.0	8.07	8.16	35.20
27	63 42 .7	10 26 .4 W	— 13	22 42	9.1	15.1	8.07	8.16	..
28	63 55 .6	11 08 .9 W	— 14	4 34	..	9.5	7.97	8.06	..
29	63 55 .1	12 38 .7 W	— 14	6 51	9.6	11.5	7.95	8.03	..
30	63 39 .7	13 53 .8 W	— 15	3 51	..	11.8	7.97	8.05	..
31	63 30 .1	14 40 .7 W	— 15	10 06	10.3	10.1	7.93	8.01	35.23
32	63 15 .0	16 23 .3 W	— 16	2 33	10.4	16.2	7.89	7.97	..
33	63 20 .7	17 14 .6 W	— 16	13 02	11.8	6.7	7.97	8.04	..
34	62 30 .3	16 50 .7 W	— 17	1 15	10.6	20.0	8.13	8.21	..
35	62 55 .5	18 15 .6 W	— 17	12 33	12.0	9.6	8.13	8.20	..
36	62 52 .2	20 14 .1 W	— 18	6 13	11.7	9.4	8.09	8.16	..
37	63 42 .3	22 07 .8 W	— 19	14 42	12.3	10.0	8.10	8.17	..
38	63 59 .2	23 02 .9 W	— 20	1 03	10.9	6.0	8.12	8.20	..
1	2	3	4	5	6	7	8	9	10

*) pH corrected for »salt-error« (-0.27 unit pH added to observed value), see section VIII.
**) pH corrected for temperature-effect after Buch, and »salt-error«, see section X.

Table 2.

Station Data	Depth meters	T °C	P_2O_5 mg/m_3	pH*	pH**
Station 26	0	8.92	25	8.07	8.16
Carnegie St. 7	16	8.92	25	8.07	8.16
	43	8.90	25	8.07	8.16
Lat. 63°20′ N	66	8.16	35.7	8.03	8.12
Long. 9°25′ W	89	8.12	39.6	8.04	8.13
	111	8.12	42.3	8.04	8.13
July 13, 1928	202	7.79	47	8.04	8.14
	290	5.95	47	7.99	8.11
G.M.T.: 13 : 57	385	2.72	48	7.93	8.09
to 15 : 02	483	0.31	..	7.84	8.02
Station 31	0	10.32	10.1	7.93	8.01
Carnegie St. 8	5	10.22	11.7	8.01	8.09
	27	9.72	15.6	8.02	8.10
Lat. 63°30′ N	54	9.08	20.3	7.95	8.04
Long. 14°41′ W	80	8.60	37.8	7.95	8.05
	107	8.44	40.7	7.95	8.05
July 15, 1928	214	8.12	44.5	7.94	8.04
	324	8.06	54.3	7.93	8.03
G.M.T.: 9 : 04	432	7.98	52.1	7.94	8.04
to 10 : 11	538	7.95	61.7	7.93	8.03
	749	7.57	55.5	7.91	8.02
	1066	4.24	40.0	7.93	8.07
Column 1	2	3	4	5	6

given the pH-values in situ of the vertical series of samples, computed as before. In this latter case, however, it was necessary in addition to correcting as above, to correct for the alteration of pH-value due to warming of the subsurface samples.

The effect of this tentative computation of surface pH-values has been to increase the pH 0.06 to 0.09 unit. The effect on the depth series of samples at stations 26 and 31 has been to decrease the vertical pH-gradients, the greatest increases in pH were found for the data from the colder bottom-water which had gone through a greater amount of warming before determination than the less cold samples. This indicates that the bottom-water is more alkaline than supposed.

It should be noted that in this warming of subsurface samples suitable

*) pH corrected for »salt-error«, see section VIII.
**) pH corrected for temperature-effect after Buch, see section X, and »salt-error«.

precautions were taken to insure no change in the CO_2 equilibrium of the sample. The magnitude of the difference between the two series of results is certainly far greater than the experimental error of the instrument used for determination.

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The Specific Gravity of Sea Water at Zero Degrees in Relation to the Chlorinity.

By

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Contribution from the Chemical and Oceanographic Laboratories of the University of Washington.

1. Introduction.

The relationship between the chlorinity and specific gravity of sea water was first definitely established by Prof. KNUDSEN and co-workers (1) about 1900. The results of this work in the form of tables (2) are extensively used in hydrodynamical investigations of the oceans. These tables afford a rapid and accurate means of calculating the specific gravity of sea water directly from an easily-performed chemical determination. The direct estimation of specific gravity is very difficult, involving apparatus and precautions which can only be obtained and realized in a well-equipped land laboratory. Since 1900, however, no attempts have been made to recheck the values given in the tables. At the request of Prof. KNUDSEN the present investigation was undertaken on a series of samples obtained from various regions of the world, through the co-operation of the International Council for the Exploration of the Sea, the International Fisheries Commission, the Scripps Institution of Oceanography, and the Carnegie Institution.

2. Experimental Procedure.

A. The Determination of Specific Gravity. Two pycnometers of the type recommended by PARKER and PARKER (3) but made of fused silica were employed in the present investigation. These pycnometers contained about 150 cubic centimeters and 175 cubic centimeters respectively, and when filled, weighed approximately 250 and 275 grams. Silica was utilized in order to minimize the errors due to thermal expansion.

An ice bath of the type used by the Parkers was also employed.

A temperature of 0° ± .002° C. was easily maintained, as was determined by the use of a Beckmann thermometer which had just been calibrated using pure water.

A balance with a capacity of one kilogram and a sensitivity of one-tenth of a milligram was used. The weights were of the ordinary brass type, calibrated by the modified method of T. W. Richards (4). Tares of pyrex glass and of the approximate weight and volume of the full pycnometers were also used.

In order to determine the constants of each pycnometer, the capillary stem was first calibrated with mercury by accurately measuring the lengths of the mercury threads. These were subsequently weighed. The stem calibrations were carefully checked and a table made of the equivalents of the stem readings in centimeters. It was found that .01 centimeter on the capillaries of the two pycnometers were equivalent to 0.048 and 0.076 milligrams of water respectively. Since the height of the liquid in the capillary could be accurately determined to 0.02 centimeter, any experimental reading could be reduced to an arbitrary standard without introducing abnormal error.

The total volume of the pycnometer to the arbitrary stem reading was determined by weighing the instrument when filled with pure gas-free water. This water was prepared by passing carbon dioxide free air through a slightly acid (sulfuric acid) solution of ordinary distilled water for a few hours, then distilling directly into a pyrex bottle. The receiver, containing the hot distillate, was evacuated, and the dissolved air removed by boiling. The water was then siphoned directly into the pycnometer, which had been previously filled with hydrogen gas (hydrogen being about $^1/_{60}$ as soluble by weight as air). Long glass tubes were fastened to the pycnometer stems and filled with the same water, so that during the process of bringing to constant temperature at 0° no dissolved air would diffuse into the pycnometer bulb. The instrument was then placed in the ice bath and allowed to come to equilibrium. It was found that no further cooling took place after three hours. The pycnometer was allowed to stand in the ice bath for six hours after which the protective tubes were removed, the overflow tube quickly dried and a reading taken on the calibrated stem. The pycnometer was of such construction that when the overflow tube was carefully dried out, the water came just to the top of the capillary below it, and also stood at a convenient height in the other calibrated capillary.

The pycnometer was then removed from the ice bath, rapidly brought to room temperature and weighed as soon as it had come to temperature equilibrium with the balance. Three weighings were made a half hour

apart, the temperature of the balance case and the atmospheric pressure being recorded each time. If the weight did not change by more than 0.2 milligram between the first and last weighing, the last weight was taken as the true weight of the pycnometer, after making the corrections necessary to reduce the weights to vacuum. The pycnometer was weighed against a tare which in turn was weighed against brass weights. The value of the specific gravity of pure gas-free water at 0° referred to water at 4° was taken as 0.9998681 (5). The density of air under the various conditions was taken from standard tables (6).

The empty pycnometer was weighed in exactly the same way except that only two weighings were made each time, as the empty instrument came to temperature equilibrium much more rapidly than when filled.

The actual volumes of the instruments and tares which were needed in order to calculate the vacuo corrections were determined by weighing in air and then in water.

The same procedure was followed for the determination on sea water except that no precautions were taken to protect the water from the air once it was in the pycnometer. The samples were never opened until just before making the determination, and were rapidly transferred into the pycnometer without coming into contact with the air.

Two hours were allowed for the sample to come to equilibrium in the ice bath; the excess water in the pycnometer was then removed as before; and the reading taken. If there was no change in the height of the water in the calibrated capillary at the end of another hour, it was considered that all the water was at zero degrees.

The results were reported in terms of σ_0. If S is the specific gravity of sea water at 0° referred to distilled water at 4°, then $\sigma_0 = (S—1)1000$.

B. The Chlorinity Determination. A modified Volhard method was used, in which approximately 25 grams of sea water were weighed to an accuracy of one milligram. A weighed excess of silver nitrate solution was added, the precipitated halides filtered off and the excess silver nitrate titrated with .05N ammonium thiocynate, using a micro buret. The silver nitrate was standardized against carefully purified sodium chloride and checked against the standard sea water of the Hydrographical Laboratories. Determinations by the Mohr method were made in order to check the values of Thompson (7) for changing chlorinity per liter to chlorinity per kilogram. Concordant results were obtained when based on the same standards used in deriving the Hydrographical Tables.

In order to compare the values of the present investigation with those of Knudsen, it was necessary to reduce the chlorinities to the basis of the 1900 atomic weights. It was found impossible to check the

standard sea water by using these 1900 atomic weights throughout in the calculations. On looking for an explanation of this, it was found that potassium chloride had been used by Prof. KNUDSEN as a standard, and that the atomic weights of potassium and sodium had not changed proportionately, as the following simple calculation shows:

	Gravimetric Factor for Cl in KCl	Gravimetric Factor for Cl in NaCl
1900 atomic weights	$\frac{35.453}{74.589} = 0.47531$	$\frac{35.453}{58.511} = 0.60592$
1930 atomic weights	$\frac{35.457}{74.553} = 0.47559$	$\frac{35.457}{58.454} = 0.60658$
Difference...	0.00028	0.00066

Taking this into account, the following results were obtained:

	Chlorinity 1930 atomic weights	Chlorinity 1900 atomic weights
Standard Sea Water ..... (6—24—27)	19.378	19.367

The value reported by the Hydrographical Laboratories for this sample is 19.368.

All values of the chlorinity reported below (which is defined as the grams of chloride equivalent to the total halides in one kilogram of sea water) except those determined by the Mohr method were reduced to vacuum.

3. Discussion of Errors.

Since the errors in the specific gravity determination outweigh any that are made in the chlorinity determination, only the latter will be considered.

While each weighing is made to 0.1 milligrams, it is doubtful whether the value obtained can be considered more accurate than 0.3 milligram. Each value of the specific gravity depends moreover on two separate weights, the weight of the instrument filled with sea water and the weight of the empty instrument (not including an equal number of weighings made to determine the volume from the weight of distilled water). There is also the error made in reading the capillary stem, which, however, will not amount to more than 0.2 milligram.

Furthermore, the specific gravity of gas-free water is not known to

the accuracy indicated by its value as ordinarily given, since different authorities vary greatly among themselves. The value of the density of air as derived from the tables is also another limiting factor, especially as it is impossible to make adequate corrections for change in humidity.

4. Sources of Samples.

The samples of sea water used in this work were obtained from the following localities:

Mediterranean Sea. These samples were collected by the Snellius Expedition and by Professor J. Giral.

Baltic Sea. Samples collected by the Thalassological Institute of Helsingfors.

North Pacific. Samples collected by Mr. Richard van Cleve of the International Fish Commission. These samples were all from one station in the middle of the Gulf of Alaska.

California Coast. Samples collected by Prof. E. G. Moberg of the Scripps Institution of Oceanography. These samples were from one station twelve miles magnetic west of the institution pier at La Jolla.

Atlantic Ocean. Samples collected by the "Carnegie". These samples were contained in bottles not up to the specifications of the International Council for the Exploration of the Sea, and were run merely to show the large variations that occur when bottles of soft glass are used. Some of the glass goes into the solution.

5. Discussion of Data.

A summary of the data from this investigation is given in the following tables. The first column, under "Chlorinity", contains the results calculated on the basis of the 1930 atomic weights while those computed from the atomic weights of 1900 are given in the second column. The latter were used in the preparation of the Hydrographical Tables. Duplicate chlorinity determinations were made in all cases and the difference between duplicates is shown in the third column. The average variation between duplicates for the thirty-six samples studied was 0.001 $^0/_{00}$ Cl. Such a variation would produce an error of 0.003 in the calculated specific gravity reported as σ_0 for samples having chlorinities of 18 $^0/_{00}$, and 0.002 for Chlorinities of 21$^0/_{00}$.

There is a very marked relationship between specific gravity and chlorinity as shown by the empirical formula of Knudsen, where σ_0 is the specific gravity expressed as (S—1)1000 at 0° referred to distilled water at 4° and Cl. is the chlorinity per kilogram of sea water.

$$\sigma_0 = -0.069 + 1.4708\ Cl - 0.001570\ Cl^2 + 0.0000398\ Cl^3$$

The observed specific gravities of the various waters at 0° referred to distilled water at 4° are shown in the first column under "Specific Gravity" in the tables. These data are all averages of duplicate samples. The variation between duplicates is shown in the second column and avarages 0.004 σ_0. The third column gives the calculated densities from the Hydrographical Tables based on the 1900 atomic weights and Knudsen's formula. The differences between the observed and calculated are shown in the fourth column. The average variation for thirty samples was + 0.019 σ_0. In all cases the observed values were greater than the calculated. It is believed that the measurements of specific gravity reported herein are more accurate than those of 1900 because advantage has been taken of the improvements in apparatus and larger samples of water were used.

The fifth column gives the specific gravities calculated from chlorinities based on atomic weights of 1930. In the sixth column are given the differences between these calculated values and those actually observed. For all the samples examined the average difference is $\pm$ 0.006 σ_0. Two interesting facts are thus presented. First, assuming the specific gravities of the present authors are more accurate than those of Knudsen's, the slight errors of experimentation in the data from which the Hydrographical Tables were computated, are very largely compensated for by the changes in atomic weights. In other words, the tables are more accurate using the atomic weights of 1930 than those of 1900. Second, the data tend to demonstrate a very slight difference in the waters of the several oceans, assuming a minimum experimental error. The waters from the Gulf of Alaska all gave a calculated value less than the experimental. The same statement applies to the Indian Ocean. The samples from the Mediterranean Sea showed conditions that were just the reverse. Rather abnormal conditions were obtained on the waters from the Pacific off the southern California coast.

These slight differences, which are either all plus or minus for all the waters examined from a given ocean, tend to indicate a very minute difference in the possible composition of sea waters. However, it may be possible that this slight variation may be due to differences in the concentration of certain dissolved gases.

6. Conclusions.

1) Accurate specific gravity determinations have been made on waters from the several oceans. The relationship between chlorinity and

Table I. Mediterranean Sea

Samples collected by the Snellius Expedition and Prof. J. Giral. March and April, 1929.

Position	Depth Meters	Chlorinity: Based on Atomic Weights 1930 ‰	Chlorinity: Based on Atomic Weights 1900 ‰	Chlorinity: Difference between Duplicates ‰	Specific Gravity: Observed σ_0	Specific Gravity: Difference between Duplicates σ_0	Specific Gravity: Calculated from Hydrographical Tables σ_0	Specific Gravity: Difference σ_0	Specific Gravity: Calculated Atomic Weights 1930	Specific Gravity: Difference σ_0
36°42′ N 1°47′ E	0	20.171	20.159	0.003	29.281	0.004	29.269	+0.012	29.289	—0.008
37°13′ N 6°55′ E	900	21.278	20.267	.000	30.899	.001	30.883	+ .016	30.899	.000
35°06′ N 17°24′ E	900	21.436	21.424	.001	31.132	.000	31.111	+ .021	31.130	+ .002
33°59′ N 21°15′ E	0	21.215	21.203	.000	30.801	.004	30.789	+ .012	30.807	— .006
33°59′ N 21°15′ E	900	21.433	21.420	.001	31.114	.002	31.108	+ .006	31.125	— .011
33°06′ N 24°28′ E	0	21.412	21.401	.001	31.094	.014	31.078	+ .016	31.095	— .001
31°36′ N 30°12′ E	0	21.398	21.386	.001	31.072	.006	31.056	+ .016	31.074	— .002
Average...	..	..	..	.001	..	.004	..	+ .014	..	—.0037

Table II. Baltic Sea.

Samples collected by the Thalassological Institute of Helsingfors. July 1929.

61°58′ N 20°04′ E	0	3.031	3.030	0.002	4.402	0.003	4.374	+0.028	4.386	+0.016
60°20′ N 26°58′ E	0	2.116	2.114	.001	3.061	.007	3.033	+ .028	3.040	+ .021
Average...	..	..	..	.002	..	.005	..	+ .028	..	..

Table III. Indian Ocean.

Samples collected by the Snellius Expedition, April and May, 1929.

7°38′ N 55°43′ E	0	19.376	19.365	0.001	28.130	0.003	28.112	+0.018	28.129	+0.001
3°48′ N 63°48′ E	0	19.208	19.197	.001	27.889	.004	27.869	+ .020	27.885	+ .004
3°48′ N 63°48′ E	500	19.443	19.432	.001	28.228	.003	28.211	+ .017	28.227	+ .001
0°04′ S 79°43′ E	500	19.394	19.383	.000	28.163	.004	28.139	+ .024	28.156	+ .007
1°06′ S 94°56′ E	0	19.278	19.267	.000	27.992	.003	27.971	+ .021	27.987	+ .005
Average...	..	..	..	.001	..	.004	..	+ .020	..	+.0036

Table IV. Atlantic Ocean.

Samples collected by the „Carnegie", August, 1928. Samples stored in soft glass bottles.

42°10′ N 47°19′ W	82	19.689	19.678	0.001	28.639	..	28.566	+0.073	28.585	+0.054
	522	19.414	19.403	.000	28.269	..	28.169	+ .100	28.185	+ .084
	2074	19.325	19.314	.001	28.094	..	28.039	+ .055	28.055	+ .039
	4140	19.321	19.310	.002	28.099	..	28.034	+ .065	28.049	+ .050
Average...	..	..	..	.001	..	..	..	+ .074	..	+ .057

Table V. Gulf of Alaska.

Samples collected by the International Fisheries Commission, June, 1930.

Position	Depth Meters	Chlorinity			Specific Gravity					
		Based on Atomic Weights 1930 ‰	Based on Atomic Weights 1900 ‰	Difference between Duplicates ‰	Observed σ_0	Difference between Duplicates σ_0	Calculated from Hydrographical Tables σ_0	Difference σ_0	Calculated Atomic Weights 1930	Difference σ_0
6°24′ N 144°4′ W	10	18.154	18.143	0.002	26.353	0.006	26.337	+0.016	26.352	+0.001
	25	18.159	18.149	.002	26.365	.004	26.346	+ .019	26.360	+ .005
	50	18.156	18.146	.002	26.366	.000	26.342	+ .024	26.356	+ .010
	100	18.176	18.166	.002	26.394	.007	26.370	+ .024	26.385	+ .009
	200	18.323	18.312	.001	26.620	.001	26.583	+ .037	26.598	+ .022
	300	18.354	18.344	.001	26.655	.010	26.629	+ .026	26.643	+ .012
	500	18.496	18.486	.002	26.860	.007	26.836	+ .024	26.850	+ .010
	1000	18.589	18.579	.002	26.992	.011	26.970	+ .022	26.985	+ .007
Average...	..	..	..	.002	..	.006	..	+ .024	..	+ .009

Table VI. Pacific Ocean.

Samples collected twelve miles off the coast of Southern California by the Scripps Institution of Oceanography. June, 1930.

32°52′ N 117°21′ W	0	18.609	18.599	0.002	27.010	0.004	26.998	+0.012	27.013	—0.003
	20	18.594	18.584	.002	26.988	.002	26.977	+ .011	26.992	— .004
	30	18.573	18.563	.001	26.954	.013	26.947	+ .007	26.961	— .007
	50	18.572	18.563	.001	26.967	.006	26.947	+ .020	26.960	+ .007
	75	18.753	18.742	.000	27.239	.010	27.208	+ .031	27.223	+ .016
	150	18.915	18.904	.001	27.461	.003	27.443	+ .018	27.460	+ .001
	200	18.945	18.934	.001	27.512	.003	27.481	+ .031	27.502	+ .010
	300	18.978	18.968	.000	27.566	.001	27.536	+ .030	27.550	+ .016
	400	19.005	18.994	.001	27.592	.005	27.574	+ .018	27.590	+ .002
	600	18.555	18.544	.001	26.934	.000	26.918	+ .016	26.936	— .002
Average....	..	..	..	.001	..	.005	..	+ .019	..	— .004 + .008

specific gravity as established by Knudsen's formula, is again demonstrated.

2) There are slight differences between the values obtained and those calculated from the Hydrographical Tables. This small error is compensated by the use of the atomic weights for 1930.

3) There is a marked constancy in the relationship of chlorinity and specific gravity in the waters of the several oceans. The observed values and calculated values of the waters do not vary by more than $\pm$ 0.000006 or $\pm$.006 σ_0.

4) Very minute differences appear to exist between the waters of the several oceans.

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Colorimetry at Sea, with a Description of a new Colorimeter.

By

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The introduction of the colorimetric determination of the phosphates, nitrates and nitrites in sea water (by Atkins, Harvey and Orr respectively) has added greatly to our knowledge of the biological properties of the sea water and has also furnished supplementary means of recognising the geographical origin of a water-mass alongside the evidence gained from the elements previously considered — mainly temperature, salinity, oxygen content and pH.

During the efforts to utilize the new methods on board our small cutter "Johan Hjort", the common instruments for measuring colour strength, Hehner tubes, different patterns and sizes of Duboscq's colorimeter, Hellige's comparator and other devices were tried and used for some time. They were eventually discarded for different reasons and a new instrument was gradually evolved, embodying the requirements imposed by the conditions of work in a small cutter with violent movements, cramped space and limited staff.

As this instrument and the manner of using it has now made it possible for one man to make about 30 determinations per hour, accurately and without strenuous effort, even in unpleasant weather, it might be of some interest to supply the following notes.

The colorimeter consists essentially of a pair of vertically moveable wedges, one filled with a permanent dye solution, the other with distilled water, and two horizontal tubes 25 or 50 cm long, one filled with the treated water sample, the other with an untreated sample, or with distilled water. Behind the wedges is a closed light-chamber with a small electric lamp fed from a big dry-cell. Another dry-cell feeds a second lamp, the light of which is thrown by a mirror on to the scale showing the position of the wedges and by another mirror on to the table

on the right of the instrument, thus supplying the light necessary for noting down the readings. The two wedges are placed in a holder which carries the scale and is moveable up and down by means of a piece of twine coiled round an axle with a knob on either end, one on each side of the casing. The two lamps are lighted when required by two small press-contacts to be touched by the fore and middle fingers of the left

Fig. 1.

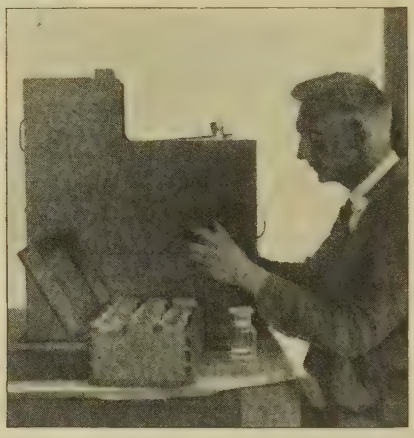

Fig. 2.

Fig. 1. Colorimeter seen end-on. An extra wedge-holder on top. Left: box of samples. Right: contant-level-bottle with Pifix pipette and 100 cc measuring bottle.

Fig. 2. Side view of colorimeter. Top of wedge-holder and funnels of tubes seen in position. Left hand of operator working lamp contacts and stopper.

hand, the thumb of which actuates the stopper while the right hand generally controls the movement of the mechanism.

When the sample has been poured into the tube, the wedge holder is moved slowly upwards until the colour strength seen through both tubes seems equal, the lower lamp button is pressed to enable the reading (in millimetres) to be made. The operation is then repeated after having moved the wedge holder so much beyond the position of equality first found that a noticeable difference is seen and it is then moved the opposite way until equality is again observed. If, now, still another pair of observations be taken in the same manner, the average may be considered to be true within 1 mm., as a range of more than 2—3 mm. between the extremes for four observations is very rare. The time consumed in making these four measurements is much shorter than is needed for reading this description. It is, of course, necessary to adjust the moveable index to the zero-point on the scale before starting work.

In order to avoid unnecessary waste of time in pouring the sample into the tubes and in emptying them, the bottles used are of the wide-necked type with glass-stoppers, and the colorimeter tubes have a wide funnel situated near one end.

The tubes are of three lengths, 12.5, 25 and 50 cm, the middle size (capacity 100 c.c.) for ordinary use, the other lengths (cap. 50 and 200 c.c.) for extra strong or weak colours, especially phosphate where the colour strength is independent of the quantity of reagent used. When determining pH it is always possible by varying the quantity of indicator (1, 2 or 4 c.c. phenolphthaline per 100 c.c. sea water, for instance) to keep the colour within the range of the wedge.

The tubes are either glass tubes with plate-glass fused on to the ends, or made of brass to make them stronger, only the end plates being glass, fastened with threaded rings and tightened with rubber. The interior is gilt or silvered, in the latter case also coated with a varnish to withstand acid solutions.

The wedges were originally made of plate glass, but as these are both dear and breakable and have the additional inconvenience of being difficult to clean in the narrowest (bottom) part, a convenient type of brass-framed wedge has been evolved, enabling the two glass panes to be easily separated and made absolutely clean before filling with the filtered colour solutions (or dist. water).

The stand, or body, is made of mahogany and the dimensions are such as to allow the worker to sit comfortably with the instrument before him on the table. The extra height thus necessitated (to bring the tubes to eye-height) is utilized for a drawer where the extra tubes, pipettes and reagent bottles are always at hand.

It has been tried to add a prism and telescope system for bringing the "images" of the two tubes together, but the advantage so gained has been found not to outweigh the loss in fine perception of the relative colour strength. As a matter of fact, one is soon accustomed to view both tube ends with one eye, looking into the tubes from a distance of 20—30cm. There must be no window or light in front of the worker, nor any strong light behind. It is best if the room is nearly dark, the lamps in the apparatus providing the light necessary for handling the bottles, filling the tubes, writing down the readings and so on. If a second person performs part of these operations, it is most convenient for him to have a weak light behind a screen or a faint light may be allowed to enter behind the operator. Two persons working together may complete up to 75 determinations per hour.

Hitherto the manipulation of big samples has been considered. The

apparatus is, however, equally useful for measuring small samples in any sort of small bottles, tubes or cuvettes. In this case a small cuvette-holder is attached between the ends of the tubes and the wedges and the cuvette with the sample inserted behind the right tube, a "dummy" cuvette behind the other and both tubes filled with distilled water. In this way the distance between the eyes and the wedges is apparently eliminated. For instance, nitrate samples contained in small angular drug bottles are easily matched without having to pour out the offensive fluid.

Finally it ought to be mentioned that the use of this apparatus for determining pH has made it possible to work out a method which does away with many of the inconveniences and errors of the earlier method which compares the samples directly with the buffer solutions.

The samples are taken in wide-necked, glass-stoppered bottles of a little more than 100 c.c. and filled completely. In this way they may be kept till it is convenient to treat them, several hours if needed, as the air has no access and temperature does not influence the colour (with phenolphthaline, which is the best and only necessary indicator for real sea water). For measuring exactly 100 c.c. a special flask with wide funnel-shaped neck and a small air-inlet has been constructed. Into this 2 c.c. of indicator (1 $^0/_{00}$ in 70 $^0/_0$ alc.) is measured by means of a Pifix pipette, filled from a constant-level bottle, and the sample then poured into the measuring bottle and from this, being thus already mixed with the indicator, into the right hand tube. The left hand wedge is filled with a permanent red dye and the value of the readings are checked beforehand by means of similar readings with standard buffer solutions from the Hydrographic Laboratory in Copenhagen, the temperature of the buffers being observed. The buffer readings are corrected to standard temperature (18°, their colour strength changing by about 3$^0/_0$ per degree difference from this temperature). The results are reduced by graphical means to a convenient diagram or nomographic scale or table (according to personal taste) and the use of the buffers is henceforth unnecessary so long as the wedges keep their colour. This may be controlled by means of a piece of red glass with its wedge-value written upon it.

When using the buffers in the old way one has to take the temperature each time and a difference from the standard temperature (which may always be expected at sea) necessitates calculation of corrections to each determination. The most careful performance of the old method with samples of 10 c.c. can only give an accuracy of about $\pm$ 0.03 in pH, while routine work with the method here described gives a perfectly assured accuracy of less than 0.01, under favourable circumstances and very careful working only 0.005.

The corresponding accuracy of the phosphate determinations may be put at 2—3 mg/m³, the colorimeter reading itself being responsible, however, for only half this amount.

The dimensions are as follows:

$l = 54$, $h = 60$, $b = 16$ cm; table space required for apparatus, accessories and a box of samples $= 75 \times 55$ cm.

The apparatus is made in co-operation by the firm of cabinet-makers Knag and the optician, Solberg Hansen, Bergen.

The Sulfate-Chlorinity Ratio in Ocean Waters.

By

Thomas G. Thompson, William R. Johnston and **Henry E. Wirth.**

Contribution from the Chemical and Oceangraphic Laboratories
of the University of Washington.

Acknowledgments.

The authors wish to acknowledge the assistance of Professor MARTIN KNUDSEN of the Hydrographical Laboratories of Copenhagen, who arranged for the collection of many of the samples in various parts of the world; the Carnegie Institution of Washington for samples from the Atlantic and South Pacific, collected by the "Carnegie"; and the University of Washington for certain financial aid.

Introduction.

The sulfate-chlorinity ratio of sea water, which has been established by one of the authors[1]) for the waters of the northeast Pacific, has been extended in the present paper at the suggestion of Professor KNUDSEN, to include waters from various points and depths throughout the world. The average of 90 samples from the northeast Pacific, analyzed in the previous work, gave a sulfate-chlorinity ratio of 0.1396. Of these 90 samples, 88 did not vary by more than 0.0004. They represented samples collected at various times of the year, taken at depths between 0 and 1100 meters and at stations over 1000 miles apart.

In this same paper it was demonstrated that waters diluted by natural means tended to show a variation in the ratio due to the sulfates in the diluting waters and to certain biological actions. Calculation of the sulfate-chlorinity ratios of waters reported in the literature showed that, while the variations were considerable, nevertheless, the 551 samples gave an average of 0.1395.

[1]) THOMPSON, LANG and ANDERSON. Publ. Puget Sound Biol. Sta. 5, 277—292 (1927).

Sources of Samples.

Given below is a description of the sources of samples of sea water used in the present study.

Atlantic Ocean. A series of six samples taken at one station in the North Atlantic by the "Carnegie".

Pacific Ocean. A similar series of twelve samples taken in the South Pacific by the "Carnegie".

Mediterranean Sea. Ten samples taken at seven stations at various localities in the sea by the Snellius Expedition, and two samples taken by Professor J. Giral off the Spanish Coast.

Red Sea. Two samples taken by the Snellius Expedition.

Indian Ocean. Eight samples collected at four different stations by the Snellius Expedition.

Baltic Sea. Five samples collected by the Thalassological Institute at Helsingfors.

Methods of Analysis.

Sulfate Determination. For sea water of ordinary concentration, a weighed, filtered sample of about 125 grams was employed. This was acidified with 10 ml. of 12 N HCl, diluted to 400 ml. and to the hot solution, 5 ml. of 3 N $BaCl_2$ was added. The precipitated $BaSO_4$ was collected in a platinum gooch crucible, having a mat made of fine asbestos which had been previously ignited, digested with hydrochloric acid, and then thoroughly washed with water. The crucible was ignited to constant weight. It was found that a Monroe crucible gave untrustworthy results because of the cracks developing in the platinum sponge on ignition. Ruppin[1]) states that the calcium present in the sea water is adsorbed by the $BaSO_4$ precipitate but careful spectroscopic examinations of the precipitates by B. D. Thomas showed that this was not the case for those reported herein.

Chlorinity Determination. Silver nitrate was added to a 25 gram sample of sea water, and the excess was titrated with ammonium thiocyanate, using ferric alum indicator, after the precipitated halides had been filtered off. The solution of silver nitrate was standardized against purified sodium chloride and against the standard sea water supplied by the Hydrographical Laboratories of Copenhagen.

Check samples were run in all cases and all weighings were made in air with brass weights.

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[1]) Ruppin: Z. anorg. Chem. 69, 232—246 (1911).

Table I.

Sample Designation	Date of Sampling	Location	Temperature °C	Depth in Meters	SO_4 Grams per Kilo	Chlorinity Grams per Kilo	Ratio $\frac{SO_4}{Cl}$
		Atlantic Ocean					
J	8-9-28	(42°10′ N) (47°19′ W)	21.18	0	2.719	19.51	0.1394
I		—	15.04	82	2.746	19.67	0.1396
D		—	7.77	522	2.704	19.42	0.1392
K		—	3.73	1037	2.706	19.39	0.1396
F		—	3.25	2074	2.697	19.35	0.1395
H		—	2.22	4140	2.691	19.35	0.1391
							0.1392_8
		Pacific Ocean					
W 7	3-25-29	(16°35′ S) (155°45′ W)	28.50	0	2.741	19.65	0.1395
W 8		—	28.46	27	2.745	19.69	0.1394
W 9		—	28.60	52	2.762	19.75	0.1398
W 10		—	26.55	101	2.769	19.89	0.1392
W 11		—	22.66	199	2.775	19.94	0.1392
W 12		—	18.03	296	2.740	19.65	0.1394
W 1		—	11.01	439	2.670	19.23	0.1388
W 2		—	8.22	533	2.655	19.12	0.1389
W 3		—	?	?	2.670	19.25	0.1387
W 4		—	2.91	1532	2.683	19.16	0.1400
W 5		—	2.27	2030	2.677	19.19	0.1395
W 6		—	2.03	2514	2.667	19.20	0.1389
							0.1394_0
		Baltic Sea					
I	7-18-29	(61°58′ N) (20°04′ E)	9.21	0	0.4286	3.03_1	0.1414
II	7- 5-29	(60°20′ N) (26°58′ E)	16.19	0	0.3000	2.11_4	0.1419
III	7-14-29	(57°22′ N) (19°57′ E)	9.53	0	0.5456	3.86_3	0.1412
IV	7-14-29	(19°57′ E)	4.70	150	0.8957	6.38_0	0.1404
V	7-21-29	(65°58′ N) (23°45′ E)	12.23	0	0.1784	1.26_1	0.1415
							0.1414

Table I (Cont.)

Sample Designation	Date of Sampling	Location	Temperature °C	Depth in Meters	SO_4 Grams per Kilo	Chlorinity Grams per Kilo	Ratio $\frac{SO_4}{Cl}$
Spanish Coast (Mediterranean)							
Sp. 1	..	(36°42′ N) (1°47′.5 E[1])	..	10	2.797	20.03	0.1397
Sp. 3	..	—	..	0	2.811	20.13	0.1396
							0.1396_5
Mediterranean Sea							
SE 1	3-29-29	(37°13′ N) (6°55′ E)	13.50	0	2.851	20.45	0.1394
SE 3	3-29-29	—	12.96	900	2.970	21.28	0.1396
SE 7	3-31-29	(36°38′ N) (12°56′ E)	13.80	0	2.885	20.71	0.1393
SE 8	3-31-29	—	13.95	900	2.998	21.44	0.1399
SE 13	4- 1-29	(35°06′ N) (17°24′ E)	15.10	0	2.949	21.14	0.1395
SE 14	4- 1-29	—	13.68	900	2.992	21.44	0.1396
SE 19	4-12-29	(33°59′ N) (21°15′ E)	15.70	0	2.962	21.21	0.1396
SE 20	4-12-29	—	13.61	900	2.990	21.43	0.1395
SE 25	4-13-29	(33°06′ N) (24°28′ E)	15.80	0	2.984	21.41	0.1394
SE 57	4-10-29	(31°36′.5 N) (30°12′.5 E)	..	0	2.986	21.32	0.1400
							0.1395_8
Red Sea							
SE 28	4-15-29	(22°56′.7 N) (37°11′.5 E)	25.80	0	3.078	22.07	0.1394
SE 30	4-15-29	—	21.61	900	3.135	22.47	0.1395
							0.1394_5

[1]) San Fernando.

Sample Designation	Date of Sampling	Location	Temperature °C	Depth in Meters	SO_4 Grams per Kilo	Chlorinity Grams per Kilo	Ratio $\frac{SO_4}{Cl}$
			Indian Ocean				
SE 33	4-27-29	(7°38′.5 N) (55°43′.3 E)	29.8	0	2.717	19.37	0.1403
SE 36	4-27-29	—	5.17[5]	1500	2.704	19.36	0.1396
SE 40	4-30-29	(3°48′ N) (63°48′ E)	29.1	0	2.691	19.21	0.1401
SE 43	4-30-29	—	10.20	500	2.717	19.44	0.1397
SE 46	5- 6-29	(0°04′.1 S) (79°43′.2 E)	28.6	0	2.742	19.54	0.1403
SE 49	4- 6-29	—	11.03	500	2.710	19.38	0.1398
SE 52	5-10-29	(1°06′ S) (94°56′ E)	28.6	0	2.693	19.26	0.1398
SE 56	5-10-29	—	1.17	4000	2.684	19.19	0.1398
							0.1399_2

Grand Average (exclusive of Baltic samples)... 0.1395_3

In the sulfate determination the average deviation from the mean on check samples was ± 0.002 gram sulfate per kilo of water, with a maximum variation of 0.005. In the chlorinity determination the average deviation from the mean was ± 0.01 gram per kilo of water.

The average sulfate-chlorinity ratio was found to be 0.1395, with an average deviation from the mean of ± 0.0003 and a maximum deviation of 0.0008. This average does not include the results obtained on the waters from the Baltic Sea. The results obtained on the various samples are shown in Table I.

Discussion.

The data presented in the above table demonstrate that the sulfate-chlorinity ratio for the different oceans of the world is remarkably constant. The series of samples taken in the North Atlantic yield ratios that are consistently low, while some of those from the South Pacific were somewhat lower than average. This may have been due to the poor quality of glass bottles used, as the samples from the "Carnegie" were the only ones that were not in accord with specifications for containers as given by the International Council for the Exploration of the Sea.

The Mediterranean samples show little variation in the ratio and are identical with those of the northeast Pacific previously reported. It is interesting to note that the samples from the Red Sea, even though they are the most concentrated, check very well with the data from other oceans. The ratios for Indian Ocean waters are slightly higher, especially for the surface samples.

The sulfate-chlorinity ratios from the Baltic Sea are abnormal. These data augment those published in a previous paper demonstrating the effects of dilution by land drainage.

Conclusion.

1) The sulfate-chlorinity ratio is remarkably constant, and using the analytical methods described, it was found to be 0.1395.

2) Sea water, diluted considerably by natural means as exemplified by the waters of the Baltic Sea, has a sulfate-chlorinity ratio that tends to vary.

Some Problems in Herring Behaviour.

(The substance of a paper read to the Challenger Society in London on January 29th, 1931).

By

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Introductory.

During autumn 1930 I made some cruises in herring drifters to observe such matters as could be observed in connection with the catches, and, specifically, to collect the fishermen's ideas about the behaviour of the herring, that might control the success or failure of fishing operations. As a result of these cruises I have reached a number of conceptions that are new to me, and that would not, I think, be accepted by the fishermen themselves. These ideas of mine are rather undefined, and founded on very little observational evidence, but they may, with the help of criticism, lead to more correct ideas, or may prove substantiated by more exact observation, and it is on the chance that they may be usefully criticised that I am exposing them here.

Method of Fishing with Drift-Nets.

I wish first to refer to the method that is used in herring fishing, because limitations of a method may lead to erroneous ideas about the presence or absence of a fish. The first limitation of a drift-net is that it is nearly stationary, or quite stationary, in the water, so that unless the herring swim into the net they are not caught. The net travels over the bottom, it is true, with the tide, but it is clear of the bottom by some distance. A second point is that there is water space above the net, below the net, between the net and the ship, and also between the constituent nets of a fleet, which are only attached to each other at top and bottom. A third point is that the net is made of fairly thick twine, which is dark brown in colour, and that there are still thicker ropes at

the head and foot of the net, as well as corks along the netrope, at the head. The fleet of nets used from each boat is from $1^1/_2$—2 miles long, and the boats may shoot their nets very close to each other, though rarely less than 200 yards apart. Fig. 1 shews in a simplified form the history of one night's fishing of a few boats, in one of which I was. The

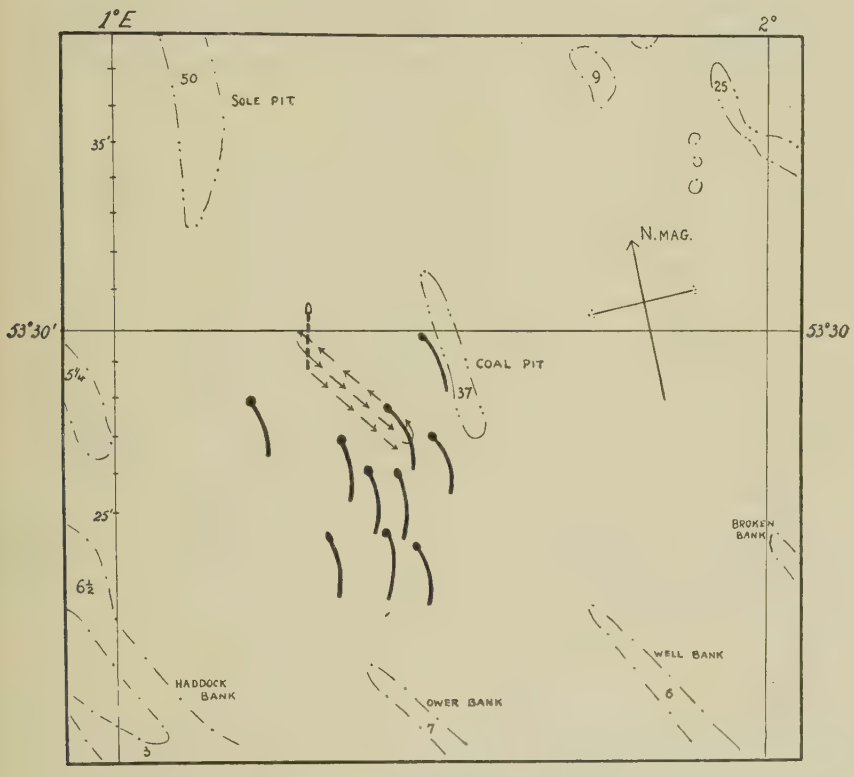

Fig. 1. Drift-net Fishing, with a Shift of Wind.
For explanation see text, p. 253.

boat carrying me shot her nets in the position shewn by a broken mark. Shortly after shooting a shift of wind occurred, of which the effect is difficult to estimate, but which I have shewn by bending the poker-signs, representing the boat in which I was, and some of the neighbouring boats, with their nets. There were many more round us, but I have only plotted those which I could identify. The course of the boat in which I was is shewn by arrows, which estimate, from the tidal-stream tables, how we travelled over the ground. The other boats moved accordingly also. On this occasion the tides were at Neaps and the estimated ellipse is less than 5 miles long, but at Spring tides it may be as much as 15 miles

long. In this case there was no crowding, until the shift of wind took place, the fleets being shot about 1 mile apart. Even so, the shift of wind gave rise to the usual feeling of being crowded by other boats' nets, a feeling which has given rise to a number of phrases in the jargon of herring fishing, such as "shot alongside of us", "shot from our stern" etc. It is important, however, to look at the matter from the point of view of a herring, which is a very small object compared with anything that can be shewn on this chart, and for whom a mile of water, or even a furlong of water, between two fleets of nets may well seem an ample domain.

It is clear that very complicated things may happen if the herring are in any way under the influence of the sea-bottom. Every boat's nets for example, covers an ellipse of ground which may be from 5 to 14 miles long and 2 to 5 miles broad. Furthermore the fleets of nets may travel in succession over the same ground, or, when they are shot at different times, boats that are alongside each other may have differred in fishing ground, so that one has been over an area not traversed by the other at all. I must say that in none of my observations in the East Anglian fishing did close precision of ground appear at all important. I must not generalise from this, for fishermen's opinion is divided about it, as regards East Anglian grounds, and, on the Plymouth grounds, precision of fishing ground is admittedly of the very greatest importance. It will be seen later that in my East Anglian fishing the movements of the fleet over the ground may be disregarded.

The Swim.

A useful term to borrow from the fishermen is that of the "swim". To define "swim":— Something happens limited in time, and space, the result of which is that herring are caught in the nets, in numbers from say five thousand to a quarter of a million per fleet of nets; this phenomenon is called a "swim" of herring. For reasons that will be considered later, the fishermen's conception of it is that some or all of the herring, normally living close to the bottom (buried in the sand even, according to many fishermen), make a sudden dash to the surface waters, and within a short space of time, say less than half an hour, have returned to the bottom, where they are uncatchable with drift-nets.

The Time of Swim.

The fishermen have a number of beliefs about the most common time in the 24 hours when a swim takes place. There is no suggestion that there may not be swims at other times, but these

times are considered most favourable. Foremost, perhaps is the "close of day", that is from sunset to about an hour or two hours after. I think it is true to say that the expectation of a swim at this time is so strong that every fisherman always tries to arrange to have his nets shot in time for the "close", as they call it, wherever he may be working. But

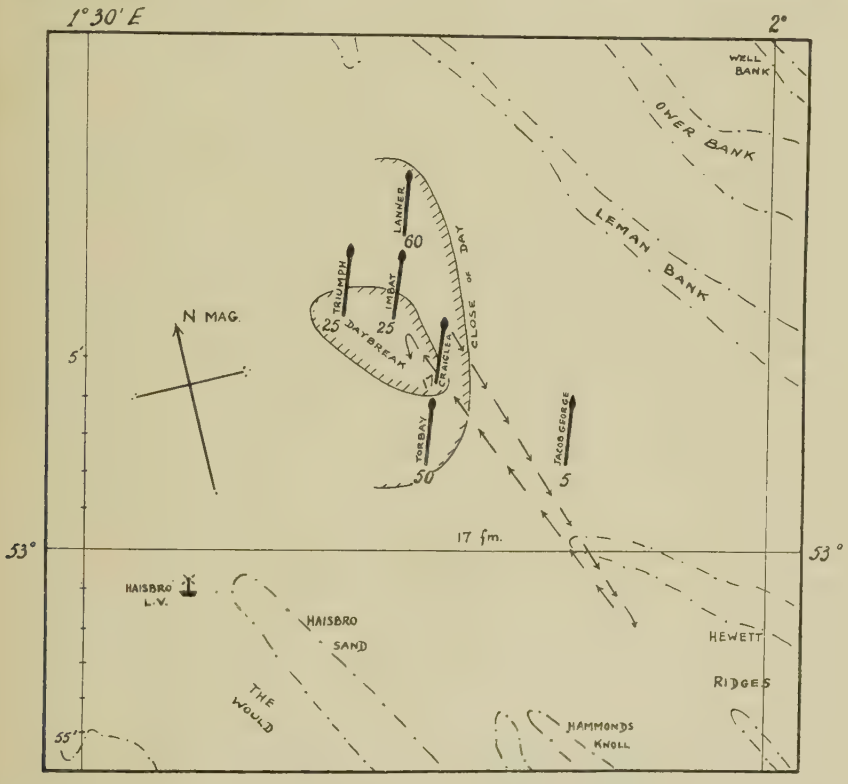

Fig. 2. Indications about the Time of Swim.
For explanation see text, p. 256.

other times are also considered favourable, though not with the unanimity and emphasis applied to the "close". Thus a swim may be expected at break of day (although few fishermen wait for this swim). Other favourable times are:— at the turn of the tide, or just as the tidal stream is beginning to accelerate, or decelerate, or at moonrise[1]). But

[1]) Since writing this paper I have had the pleasure of criticism of the typescript by two well-informed skippers: Capt. R. Balls of Yarmouth and Capt. S. Strowger of Kessingland. They agree that Low Water Slack is perhaps the most favourable time of all.

the observations from which the fisherman deduces the time of swim are, at best, merely indications, usually pointing to some period of one, two or three hours duration, during which, on most nights, one or more of the significant events (moonrise, slack water and the like) is certain to have occurred. Consequently, though believing in the "close" of day swim, about which there is so much unanimity, I am inclined at present not to accept the theories about the coincidence of swim with tidal or lunar phenomena, though not yet to reject them. An actual example (Fig. 2) of a night's fishing, when there were indications of swims at the close of day and at dawn, will make clear the sort of experience on which the fishermen's beliefs are based. I have no other example in my short experience, a dozen or so nights' fishing, in which the indications are so clear, and they are certainly not indubitably clear in this one.

Fig. 2 again shows only such boats as I could identify, by the fishing numbers, or because the crew of the ship I was in recognised the vessel. I was in the "Craiglea", whose approximate course is again shown by arrows. The catch of each boat is written in against the end of the nets. We started to haul our fleet at midnight and only found enough fish in the first few nets to cause us to expect 4 crans in the whole fleet, but finally took 17 crans. (A cran contained about 1400 herring, of the size we were taking). Hauling took 7 hours, and the last 20 of our 107 nets were only taken from the water after daylight (Sunrise 6.20 a.m.). These nets contained about 14 crans of very lively fish, markedly lively. There was, therefore, a swim, that only affected nets that were in the water at daybreak. Of course, from our own observations, there is the alternative explanation that the swim only occurred at one end of our fleet, but that would not explain the liveliness of the fish, and, also "Triumph", and "Imbat", who shot with us and hauled with us, had the same experience; nearly all their catch, 25 crans in each case, being in the last quarter of the fleet, that was hauled after daybreak. But there were two boats near us, "Lanner" and "Torbay", both of whom had greater catches than "Imbat", "Triumph" and "Craiglea", and there was this difference between the two groups of boats, that "Lanner" and "Torbay" both were shot earlier in the evening, getting 50 and 60 crans, whereas "Imbat", "Triumph" and "Craiglea", with 17—25 crans, were not shot early enough to "get the close" of day, according to fishermen's definition. The actual times of the important events were:— Sunset 5.15 p.m., "Lanner" and "Torbay" shot at about 6.30 p.m., "Craiglea" etc. shot 7.0 to 7.35 p.m., when it was quite dark. It appears then that the swim at the "close" occurred at 6.45 p.m., or near that time, $1^1/_2$ hours after sunset, and only $^1/_4$ hour before we shot, $^1/_4$ hour too late.

This, at any rate, was the explanation of the phenomena by my skipper[1]).

Area of the Swim.

Now the "Jacob George", 4 miles to the S.E. of us, experienced neither one swim nor the other. This leads to the conception of the swim as limited in area. I have no observations from which I

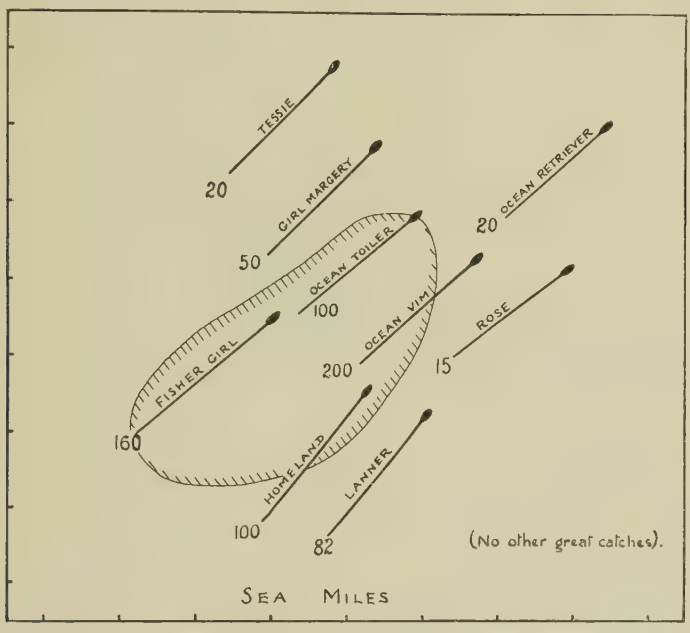

Fig. 3. Observations on the Area of Swim.
The catches of all boats recognisable by the observer, who was in the "Ocean Vim", are recorded against the line representing approximately the relative position of the fleet of nets. (Figures are "crans"; there were some 1400 herring to the cran on this occasion). It is to be observed that the catches contour, roughly, and one may distinguish an area wherein catches of 100 crans or more were obtained.

can precisely define the usual area of the swim, but it is to be seen in Fig. 2 that the swim at the "close" affected two boats whose nets were on the average about 6 miles apart, while the daybreak swim affected a smaller area, so far as my observations went, about 3 miles by 2. Generally speaking, I never found only one boat with a good catch, the swim always affecting two or three neighbouring boats.

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[1]) Captain Balls *(vide supra)* is however of the opinion that the "close" was over before "Lanner" and "Torbay" shot. He thinks the important event was Slack Water, at 6—7 p.m.

In Fig. 3 I have rather better observations on the area of swim, because, although I did not succeed in identifying the boats to the S.W., I know, quite definitely, that there were that night no other great catches, which, had they occurred, might prevent my closing the rough contour that I have drawn. In this case there was some activity, sufficient to yield 15 crans or more, over the whole area observed, 8 miles by 5 miles; but the great activity, 100 crans or more, covered a smaller area about

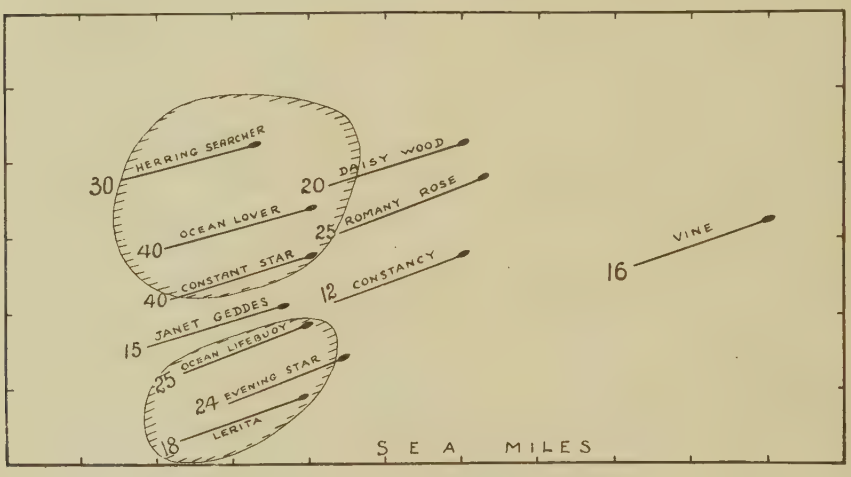

Fig. 4. Observations on the Area of Swim.
On this occasion the area of good catches (20 crans or more) is divided by the poor fishing of the "Janet Geddes". (But see footnote to this page).

5 miles by 3 miles. Sometimes there was a more complicated picture, as in Fig. 4. Here the good catches were in two patches, whose minimum area is shown by the rough contours (I have not really observations sufficient to justify closing the contours on the outside). These patches were separated by a barren strip fished by the "Janet Geddes" and "Constancy"[1]). Now, it is to be observed that no account of the sea-bottom need be taken in these charts of catches showing a tendency to contour. The catches contour, more or less, on the positions of the fleets in the water merely, and not in respect to their position over the bottom, which is traversed by the different fleets in succession. It is possible to conceive that the herring are, nevertheless orientated to the bottom, if the swim takes place in so short a time that it only affects boats near that piece

[1]) Captain Balls, while not denying that barren strips may occur, points out that "Janet Geddes" and "Constancy" are boats whose fishing power is inferior to the remainder, owing to fewer nets etc.

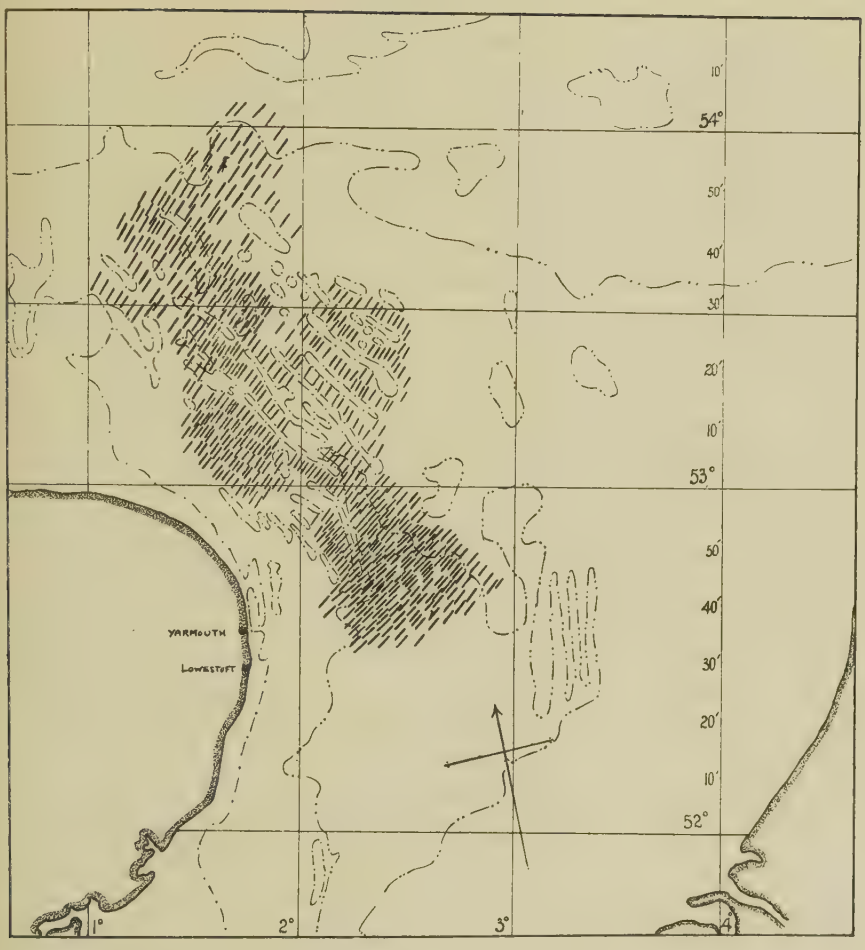

Fig. 5. Imaginary Chart shewing all Boats fishing on Oct. 18/19 1930. Each stroke of the pen represents one boat and her nets, roughly to scale, and approximately the correct number of boats are recorded. As regards position of fishing the chart is somewhat speculative.

of sea-bed at that time. This is the fishermen's explanation, and, so far, it is not precluded, for we have seen that the swim may indeed last for only a short time. But the observations do not demand any account to be taken of the bottom at all, and preclude the conception of the herring, for example, maintaining their position over the bottom by swimming upstream for the whole night, for in that case many boats would fish the shoal of herring. My own explanation of the phenomena will be given later.

Direction of Swim.

The phenomenon which is disturbing to the fishermen's explanation is that of "direction of swim". It is possible, when one hauls the net, to see which side the fish came in from, and the lore on this subject presents us with a great difficulty, if we accept it. Fig. 5 is an imaginary chart showing all the boats that were fishing on the night in the middle of October, when the ship in which I was (the "Ocean Vim") had a 200 cran shot (Fig. 3). The chart is approximately correct as to the number of boats engaged, and the length of the fleets of nets, shown by short lines. As regards the distribution of the boats I have had to imagine where they would probably be, and in this matter the chart is naturally approximate. The position of the "Ocean Vim" with her 200 crans was near $53^1/_2$ degrees North and $1^1/_2$ degrees East. On this particular night the wind was W.S.W. when we shot, so that the nets lay roughly N.E. and S.W., and the slight shift of wind that occurred after we had shot was accompanied by the wind becoming weak, so that the nets continued to lie in the same approximate direction. When we came to haul it was very noticeable that the great majority of the herring entered the net from the N.W. side. In the first few nets, where we had only a moderate average of quantity, I noted that the herring were both ways in the net, in little parties each way, but that the thickest parties were from the N.W. After the halfway buoy, whence the herring became thicker and thicker, I noted that 90 per cent of the herring were from the N.W. side. This might be of little importance, were it not that the fisherman says: "Of course, when fishing anywhere in the Home Fishing, except at Smith's Knoll[1]), the herring will seem to come from the N.W. or N., but at the Smith's Knoll they come from the westward and, inshore also, they come from the westward, that is off the beach. It does not matter how close you are to the shore they come off the beach." My own experience is insufficient to check this statement about direction, but on the only occasions, three in number, when I noted that the herring were markedly from one direction, the direction was from the N. to N.W. But there is such unanimity about it that I am inclined to accept it. Similarly with the statement about longshore herring apparently coming from the beach. I have not seen this, and want more confirmation of it, but one or two driftermen who have been longshoring are so positive in the matter that I cannot

[1]) "Anywhere in the Home Fishing" signifies approximately the area included in Fig. 5. Smith's Knoll is a submarine ridge at the south end of which is the Lightship of the same name in Lat. 52°43′ N. Long. 2°17′ E.

disbelieve it[1]). As regards the herring coming from the westward at the Smith's Knoll, I have no reason to doubt it, though less reason to accept it than with regard to the other two parts of the statement. But this direction of a swim presents a serious mental difficulty. If the herring always tend to come from the northward, whatever the state of the tide, and the fishermen are positive that the direction of the tide makes no difference, one must discard the fishermen's ideas about herring rising from the bottom, unless we add to it that they tend to slant in a particular direction in their rising, irrespective of what way the water is moving relative to the ground. This is not impossible, but it does not commend itself as probable behaviour. Furthermore, how can herring come always from the beach, and how can there be a direction of swim and yet no blanketing of a boat by one whose nets are only a mile away to the northward? Again, why, when a night of universally big catches is suddenly made, are these catches made simultaneously over the whole area, as they were on a night early in November of this year? If an enormous arrival of herring took place from the northward, one would expect them to arrive first at the northerly part of the area, not simultaneously everywhere.

Before attempting to answer these questions we will pass on to some other reputed factors in the inducement of swims or of good catches.

Other Factors.

In the first place there is universal agreement that "shear", or very clear water, is unpropitious for herring fishing, and turbid water, "milky", favourable. I have seen this criterion fail more often than I have seen it work, even in my short experience; that is, the greatest catch I have seen was pulled out of water so clear that I could easily watch the *Orca* playing around and underneath the ship; and propitious water, according to the skipper, has more often than not heralded a poor catch. Nevertheless, so unanimous is the opinion in the matter, that I am almost compelled to believe that it is not imagination, nor an old tradition that ought to be exploded. (One such erroneous tradition will be referred to below). The explanation that immediately suggests itself is that water which is very clear will be devoid of planktonic food for the herring, and "thicker" water will tend to be richer than clear water. But, in the East Anglian herring fishery, as well as

[1]) There is some difference of opinion about this. The longshoremen I have met at Yarmouth give the account of herring apparently coming from the beach, but Captain Strowger is positive that at Kessingland, just south of Lowestoft, they come from the S.

in most other herring fisheries, but not all, the fish are ripening towards spawning, and are not feeding at all. This explanation, therefore, is at fault, if we believe that the turbidity of the water affects the fishing at this phase.

There is much talk about the Moon. In the East Anglian fishery the heaviest catches, year after year, are made at Full Moon, or near it. I have Mr. Hodgson's authority for this fact, which is shewn in the statistics of daily landings, and is denied by none. One might have thought that this was a tidal phenomenon, and it may partly be so. Certainly the fishermen like "strong tides", whether at Full or New Moon. But the phenomenon is, I am told, not so clearly marked at New Moon, and the difference is sufficient to prevent us accepting the tidal explanation, in so far as it is any explanation, as the whole story. It seems that Full Moon, as such, has the effect of increasing the catches, and I am told that this is the case, even when the sky is consistently overcast at Full Moon. At this point we may refer to the exploded tradition in connection with the Moon and the fishery near Plymouth. In former times the expectation of poor catches on moonlight nights was, I am told, so definite, that most of the boats would avoid having their nets shot during moonlight. Nowadays they shoot their nets, taking no account of moonlight, one way or the other, and no effect has been noticed by them. Often a good week's fishing coincides with a week of bright moonlight nights. The explanation given me is that in the old days the fishermen were in error, and only found their error when, by accident, a boat happened to fish on a bright moonlight night, and make a good catch.

Scepticism.

I have not recounted all the lore which I heard, for instance the effect of direction of wind, and so on. In all these matters, except perhaps the "close" of day tradition, and the turbidity tradition, there seems to be a degree of scepticism to be found, among the modern fisherman. I have only once heard it put into words, by the same man who gave me the version above of the explosion of the myth about moonlight at Plymouth. He put it roughly that the catching of herring is a matter of chance, and that the traditions are simply due to the desire of the human mind for an explanation. "If they get a poor catch, they'll always find something to explain it". I mention this here because it emphasises the general observation that chance plays an enormous part in herring catching. And that is significant from our point of view.

The Problem.

It is universally agreed that the behaviour of the herring is a mystery. No fisherman attempts an explanation of even all the phenomena I have referred to here. In fact, there has for some centuries been a tendency to regard the mysteries as so deep that it would be foolish, perhaps even impious, to attempt an explanation. One skipper I was with seriously ascribed the failure of the Shetland fishing in 1930 to a judgment on the people for beginning to think they knew something about the herring.

Let me attempt to state the main mystery as I see it. There is a tendency for herring to enter the nets from a definite direction, and yet there is no screening, neither from the nearby shore, nor from the nets of other ships, which may be only a furlong away in the direction from which the herring appear to come; and, although there is direction, the catches may be simultaneous all over the whole area of the fishing, or, whereas the direction is apparently north to south, the large catches may first be made to the southward, or may be quite irregularly distributed.

The Hypothesis.

My provisional explanation is on these lines: Firstly the herring, when normally proceeding about its business, can see the net, and avoid it, by going round the fleet, under the fleet, over the fleet, through rents in the net, or between nets. Secondly, the shoal of herring is subject to crowd psychology, such as may be seen in human beings during a riot, but in flocking birds every day, and in herding mammals. The chief characteristic of crowd behaviour, as opposed to individual behaviour, is extraordinary susceptibility to telepathic impulses, and unquestioning obedience to the instinctive response, making concerted action. Particularly effective are impressions causing fear, which results in the well known phenomenon of panic. Thirdly, it is suggested, that the herring, when under any crowd impulse, is more or less unable to see the net and avoid it, in its subsequent instinctive reaction. States of mind which may produce this effect may be several, for example panic, sexual excitement, migratory impulse. With regard to the last, it is commonly held that migrating birds are "not themselves", but are in a state corresponding to a kind of ecstasy; they are certainly immune to fear of normal danger, they fly faster than they are apparently able in the ordinary state, and probably withstand unusually great fatigue.

According to this, a "Swim" is the effect of local excitement, panic from dogfish or whales, or from finding themselves in shoal water; or

a sudden desire to proceed with their migration, or a detached sexual dance. A great catch all over the area, such as occurred at Full Moon on Nov. 5th and 6th, 1930, 100 million herrings, is due to a widespread excitement. In this instance, Mr. Hodgson tells me that the fish involved were mainly young fish maturing for their first time, and one may, legitimately according to my thinking, visualise a widespread ecstatic carnival, following the sudden awakening, under the influence of the Full Moon, of the instincts that would cause them to breed, perhaps at the next Full Moon. There is nothing new in such an idea, when one remembers the pandemonium of bees about to swarm, the sudden and simultaneous flight of the ants, or the more formal dances of the Crowned Cranes.

The explanation, that the herring normally avoids the net, so that all the sea may be full of herring and none caught, but that excitement causes it to be caught, meets our most serious difficulty, namely that there is a tendency to direction in the entry of herring into the net, but no screening. The herring appear to come from the northward more often than not, because the herring in a particular locality feel a simultaneous urge to proceed with their migration, which is from the northward. Suddenly the impulse passes, and the herring are themselves again, and will avoid the net. The "swim" is over. The herring along the shore appear most frequently to come from the beach, because parties are constantly finding themselves in shoal water; these panic and shoot away from the beach, causing panic and an offshore dash, even in those that are in no danger from the shoal water. (At the Smith's Knoll the same thing may happen on the shoal water there: the water is markedly turbid at the Knoll, more so than anywhere else in the area, and sudden danger of stranding may be more common than elsewhere).

The explanation also holds in a number of other details. A net will be more visible in clear water than turbid; yet good catches may be made even in crystal clear water if the panic is sufficient. Good catches often consist of herring packed in nearly every mesh, so close that one wonders how they can swim. My friend, Mr. Ford, has demonstrated to me how the captive mackerel at Plymouth immediately pack, until they appear one solid mass, if one bangs on the glass of the aquarium. The net will be very plainly visible when there is much phosphorescence, and phosphorescence is known to be unpropitious. Strong tides are better for herring fishing, because strong tides stir up the bottom, cause greater turbidity; and perhaps also cause greater activity of the bottom-living fish, some of whom are enemies of the herring, which will be more liable to panic when their enemies are on the move. Herring fishing is mainly

a matter of chance, because the incidence of local panic may depend on a number of frightening factors, which may occur anywhere. A "swim" only lasts a short time, because it depends on an abnormal emotional state of the herring, and such states are not usually long sustained. A general heavy fishing over a large area generally lasts for an appreciable time, two nights or so, because an emotion which is strong enough to affect the whole population will be strong enough to be somewhat sustained. Local good catches are, however, rarely repeated in exactly the same place on the following night, although a region that is favourable one night may be favourable the following night, or may not. There may be a shoal of dogfish about, staying in the same place for a few nights, and causing panic here and there.

On the other hand traditions about the time of swim, if substantiated, are not yet explained.

There are two implications of the hypothesis that are of economic importance: In the first place, if my explanation is right, the catches probably only represent a small proportion of the stock, which proportion could probably be increased without detriment. Secondly, it should be possible, by experimenting with nets of less visibility in the water, to obtain a greater return of herring for the expenditure of effort.

Summary.

The paper is a preliminary note of work on the factors, other than stock, affecting catches of herring in drift-nets. The incidence of good catches has for many years been mysterious. One of the hitherto unexplained phenomena is that there is apparent direction in the movements of herring taken by the net, yet there is no screening by neighbouring nets, nor, it is said, by the shore. Another difficulty is that, whereas there is direction in the entry of herring into the net, there is no progression of good catches from one part of the fishing area to another part. A provisional explanation is offered on the lines that herring, in a normal state, can see the nets and avoid them, so that the sea may be full of herring, yet none caught. When, however, they are under the influence of crowd excitement (due to panic, sexual excitement or migratory impulse) herring are more or less unable to see the net, and are caught. A number of fishermen's beliefs about herring are recorded.

A critical Study of the Scales of two Specimens of starved and excessively fed Trout — *Salmo irideus*.

By

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Introductory.

In the course of an investigation of the effect of environmental changes on the width of the concentric rings on the scales of *Salmo irideus* I had occasion to examine the scales of a number of fish which were hatched and reared for two years at the Nailsworth Trout Farm. These fish were fed by hand during the whole period of their life, and the scale rings were found to be, more or less, uniformly spaced; they showed no indication of alternating "summer" and "winter" rings. The width of the rings showed no correlation with the temperature of the environment, and the conclusion was reached that the width of the rings on the scale depends on the intensity of the food supply and not on the surrounding temperature (Bhatia, 2).

An attempt to test this conclusion by experimental methods has recently been made by Gray and Setna (5). Selected fish were exposed for some months to a controlled diet, some fish being provided with abundance of food, others being given a much more restricted diet. It was found that a limited number of scales from a fish fed abundantly for eleven months exhibited a distinct increase in the width of the peripheral rings, whereas scales from a fish on restricted diet showed a distinct decrease in the width of the peripheral rings. Such selected scales are illustrated in the paper of Gray and Setna, who confirmed my conclusion that the width of the rings is determined by food supply and not by temperature. It is important to note that although selected

scales are specific in the sense that they are peculiar to well fed or starved fish respectively, by no means all the scales of a given fish exhibit clearly the correlation between food supply and width of the rings. The examination of a large number of scales from both well fed and starved fish showed them to have more uniform spacing throughout, since the width of the rings at the periphery was not consistently larger or smaller than the normal. In a few cases the starved fish scales possessed a few rings on the periphery as broad or even broader than the peripheral rings on a typical excessively-fed fish scale. And conversely, some scales of the excessively fed fish showed a few comparatively narrow rings at the periphery. A doubt was therefore expressed that the definite bands of broad and narrow rings obtained in a few scales might be a mere variation, for the scales do show a great deal of individual variation in their size and shape and in the number and width of the rings, and thus these particular rings might not really be the result of excessive feeding or starvation as had been concluded in the paper already referred to, for if it were so, the majority of the scales should have been similarly effected. It was, therefore, expedient to examine a large number of scales from an extensive area of the trout, carefully measuring the width of the peripheral as well as the central rings, and then compare the total of the results. A systematic examination of material derived from the stock reared by GRAY and SETNA shows, however, that even in scales which show no obvious correlation between food supply and the width of the rings, such a correlation actually exists.

Methods.

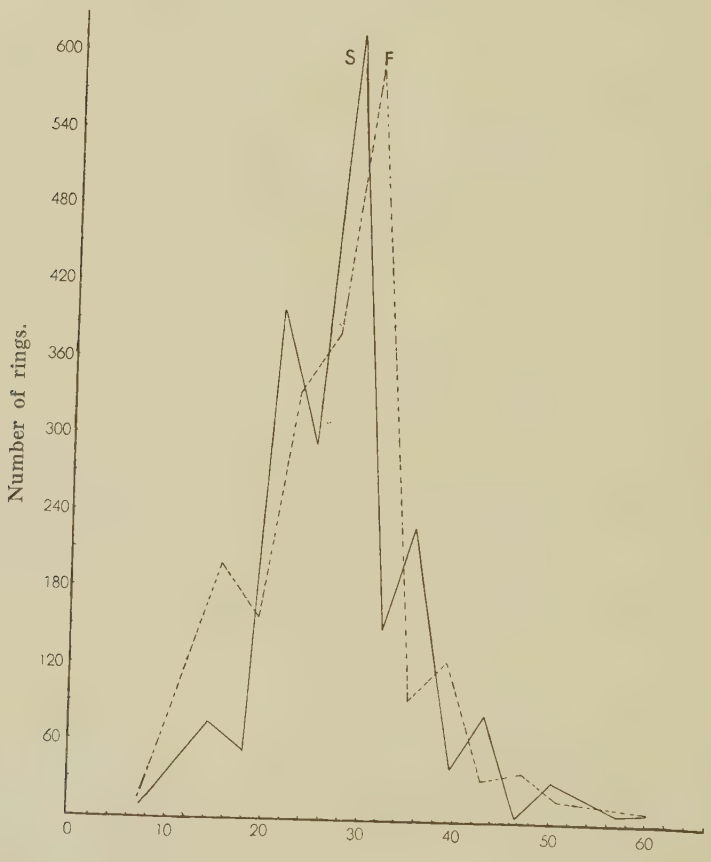
One well fed fish measuring 33.5 cm. in length, and one starved specimen 26.5 cm. long were selected from the material of GRAY and SETNA. Scales were removed from each specimen from head to tail along a line $^1/_4$ inch above the lateral line on either side. A large number had to be rejected for having imperfect centres or being otherwise damaged, but one hundred quite perfect scales were selected from each specimen and mounted in glycerine. GRAHAM's method was adopted for measuring the width of the rings.

Data.

1) The size of the scales was found to vary considerably. The starved specimen had scales 2 to 2.6 mm. long and the larger fed specimen from 2 to 3.25 mm. No definite correlation could be found between the size of the scales and the number or width of the rings, but it appeared that

the larger the scale the more numerous the rings and not necessarily wider.

As described by Miss ESDAILE in the Salmon, the number of circuli on the trout scales seemed to increase from the head to the adipose fin and then diminish towards the tail, though not to the same appreciable extent.



Graph. 1.
Width measurements in μ of 20 innermost rings in 100 scales.

2) The width of 20 innermost rings — next to the centrum — were measured in each of the 100 scales of the fed (F) and the starved (S) specimens giving a total of 2,000 rings measured in each case. They varied in their widths from 7.7 μ to 60 μ. Graph 1 shows the number of these rings of varying widths in 100 scales of the S and F specimens. The two curves obtained almost overlap each other. These rings were formed during the time when the two specimens were living under

identical conditions in the hatchery. The ring-growth maxima and minima practically correspond in the two cases. The largest number of rings of the S specimen are 29 μ, whereas the majority of the rings of the F specimen are 31 μ. This difference has no greater significance than an individual variation in the same way as the S specimen has

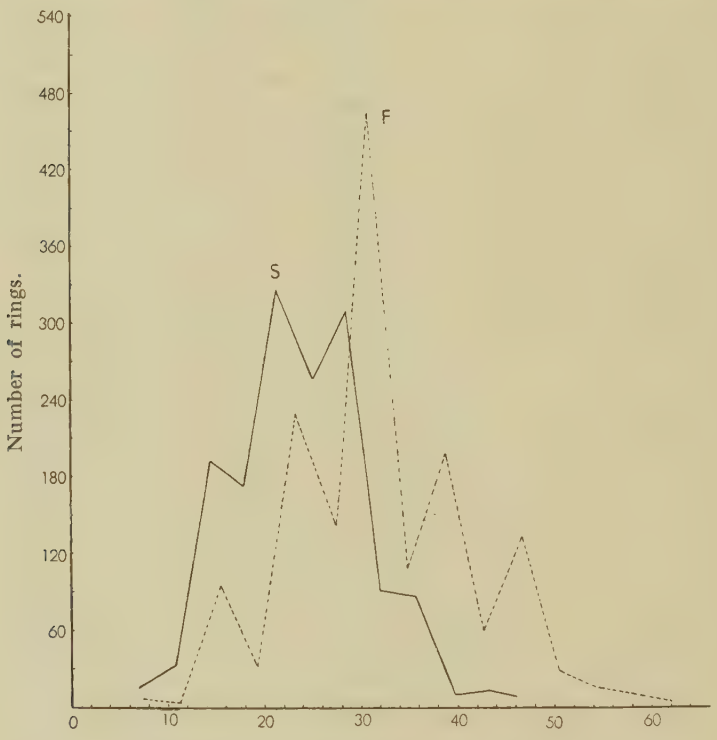
Graph 2.
Width measurements in μ of 20 peripheral rings in 100 scales.

a larger number of rings as wide as 35.8 μ and 43 μ than the F specimen. The number of the narrowest (7.7 μ) and the widest (60 μ) rings in the two cases is almost identical.

For the period during which these rings were being formed the fish had been exposed to the same conditions of food supply, and consequently the two specimens formed similar rings on their scales.

3) It is almost impossible to determine on their scales the point

where the two specimens were separated and put under different conditions of food supply. One (F) was fed excessively twice a day, and the other (S) only once every other day. However, the difference in their nutrition must necessarily act on the scale periphery, if at all. It was supposed that the outermost 20 rings were formed during the last 11 months of the fish life on abundant or deficient food supplies respectively.



Graph. 3.
Width measurements in μ of 15 peripheral rings in 100 scales.

Graph 2 shows the distribution of these peripheral rings of varying widths in 100 scales examined from each specimen. The two curves obtained no longer overlap (compare Graph 1). Curve S has shifted towards the left indicating an increase in the number of comparatively narrow rings; the widest rings present do not exceed 50 μ. Curve F, on the other hand, shows an increase in the number of wider rings. Although there is still an overlapping of the two curves on the right, curve S hardly ever reaches the heights of F.

The peripheral rings of the starved fish are, on the whole, narrower han the peripheral rings of the excessively fed fish,

4) It is quite probable that the number of rings formed during the period of starvation or excessive feeding was less than 20. In that case a number of rings would be included in the above measurements which were really formed during the earlier life in the hatchery, and those, we have seen (Graph 1), are practically similar in their widths. Graph 2, therefore, does not represent the exact comparisons between the peripheral rings of the starved and the fed fish scales. If there was a gradual closing up or widening of the rings as a result of the changes in the food supply, the more peripheral rings should show a still greater contrast. Only 15 outermost rings were therefore measured in each of the 200 scales from the two specimens, and their numbers plotted against their widths in Graph 3. The curves S and F are quite distinct. Whereas the curve S shows a further decrease in the number of the wide rings — the widest being only 46 μ — and an increase in the number of narrower rings, curve F shows just the opposite — a further increase in the number of wider rings and a reduction in the number of narrower rings, though it may be noted that the greater majority of the rings are still 31 μ in width.

Conclusions.

It is clear from the above data that although it is difficult, if not impossible, to determine from the examination of the majority of the individual scales the effect of the rich or poor food supplies on the formation of the scale rings, the measurements of the width of rings of a large number of scales obtained from a large surface of the body show *collectively* the food effects in quite an obvious manner. A rich nutrition produces on the scales comparatively wide rings while a poor nutrition results in the formation of narrow rings.

It is possible, but not altogether likely, that the excessive nutrition obtained by the fish in one case and its deficiency in the other were not greatly different from the normal consumption of food in the hatchery, so that the scales did not show, except in a few cases, a distinct broadening out or narrowing down of the rings as they do in nature, where the discrepancy between the summer and winter food supplies is obviously very great.

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Die Turbinen und die abwärts wandernden jungen Lachse und Forellen.

Von

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Im Jahre 1927 machte ich für die Dänische Biologische Station eine Musterung durch das Gebiet der Flüsschen Sneum Aa und Kongeaa mit allen ihren Zuflüssen. Die zum Aussetzen von Lachs- und Forellenbrut geeigneten Stellen wurden auf einer Karte vermerkt, ihre Qualität wurde beurteilt und es wurde berechnet, wieviel Brut an jeder Stelle ausgesetzt werden kann, damit die vorhandene Naturnahrung in entsprechender Weise ausgenutzt wird.

Hierbei wurde indessen bei den betreffenden Stellen nur der schätzungsweise beurteilte Reichtum an Nahrung für die Brut und das Areal berücksichtigt. Es genügt jedoch nicht, dass der Jungfisch in den Flussgebieten aufwächst, er muss auch wohlbehalten das Meer erreichen können. Abgesehen davon, dass unter gewissen Umständen ein Teil des Meerforellenlaichs sicher zu Bachforellen oder Seeforellen wird (auf Grund des Mangels an Seen, ist in Sneum Aa oder Kongeaa die Entwicklung zur Seeforelle allerdings ausgeschlossen), werden allerhand Hindernisse eintreten, die es den Jungfischen erschweren, ins Meer zu gelangen. Von diesen Hindernissen soll hier nur eins behandelt werden, nämlich das durch die verschiedenen Arten von Kraftgewinnungsanlagen verursachte; es sei nur noch erwähnt, dass auch Wiesenbewässerungsanlagen, Forellenteichwirtschaften, Aalkisten, Aalreusen, verunreinigte Flussstrecken und Stellen mit vielen Raubfischen oder mit eifrig betriebener (ungesetzlicher) Lustfischerei von unausgewachsenen Fischen ein Hindernis bieten können; in dem einen Wasserlauf spielt für die ungehinderte Wanderung der Jungfische nach dem Meer eine oder mehrere dieser Schwierigkeiten die grösste Rolle, in einem andern Wasserlauf sind es vielleicht andere Umstände, die

hindernd wirken; in nahezu allen dänischen Flussgebieten, die sich zum Aufwuchs von Lachs- und Forellenbrut eignen, müssen die Jungfische auf der Wanderung nach dem Meer eine oder ein Paar, ja sogar oft mehrere Wasserkraftanlagen passieren, es ist daher von grosser Bedeutung sich Klarheit darüber zu beschaffen, ob durch diese den Fischen irgendein Schaden zugefügt wird, und ferner, wie gross der Schaden ist.

Das Gesetz berücksichtigt diesen Umstand ausdrücklich. Im Gesetz über die Binnenfischerei vom 2. Juni 1917 heisst es im § 10, dass oberhalb von Mühlen und anderen industriellen Anlagen, sofern sie durch Turbinen getrieben werden, in der Zeit vom 1. Mai bis zum 30. September ein Gitter angebracht werden soll, und zwar in der Weise, dass alles Wasser für die Turbine das Gitter passieren muss; die Öffnungen dieses Gitters dürfen höchstens 20 mm gross sein. Die älteren Formen der Kraftanlagen mit Wasserrad sind jetzt verhältnismässig selten, ihre Bedeutung für die Fische ist deshalb untergeordnet; sie bieten übrigens kaum ein nennenswertes Hindernis für den abwärts wandernden Fisch, jedenfalls kaum für Kleinfische, wie abwärts ziehende Junglachse und Jungforellen.

Die Turbinengitter sind nicht leicht im gesetzmässigen Zustande zu erhalten. Es dauert oft nicht lange, dann sind an einigen Stellen die Stangen verbogen, so dass sich hier eine über 20 mm grosse Öffnung bildet. Für Kleinfische bieten also die Gitter nur selten ein absolutes Hindernis für die Passage. In noch geringerem Grade ist das natürlich der Fall, wenn die Zwischenräume zwischen den Stangen schon von vornherein über das gesetzliche Mass hinaus zu gross waren, oder wenn einige Stangen ausfallen.

Selbst wenn das Turbinengitter gesetzmässig ist, ist seine Wirkung nicht wie ursprünglich beabsichtigt verbürgt. Befindet es sich vor einer kräftigen Turbine, kann die Saugkraft so stark sein, dass der vor das Gitter gelangte Fisch von der Strömung unwiderstehlich mitgerissen wird, schliesslich am Gitter festgesogen wird und zu Grunde geht. Das ist besonders da der Fall, wo sich das Turbinengitter tief im Inneren eines Werkkanals befindet, denn hier können sich die Fische nur mit Schwierigkeit der gefährlichen Nähe des Gitters entziehen; wo sich ein solcher Werkkanal befindet, ist das Gitter am besten am Anfang des Kanals anzubringen, damit kein Fisch hineinschlüpfen kann. Dies aber stösst auf eine weitere Schwierigkeit; nach dem Fabrikanlagegesetz sind nämlich (zur Vermeidung von Unglücksfällen) unmittelbar vor den Turbinen Gitter anzubringen; es ist natürlich unbequem, an mehreren Stellen Gitter anzubringen, und man kann deshalb nicht erwarten,

dass die Besitzer ohne ausdrückliche Anweisung besondere Gitter weit ab von den Turbinen einbauen, und für eine solche Anweisung gibt es keine rechtsgültige Bestimmung im Gesetz für die Binnenfischerei. Im § 11 des neuen Gesetzes für die Binnenfischerei, vom 31. März 1931, ist die Bestimmung jedoch verbessert worden. Es heisst da, dass das Gitter wenn möglich beim Eintritt zum Werkkanal angebracht werden muss, und dass bei Neuanlagen seine Konstruktion und Unterbringung vom Fischereidirektor genehmigt werden soll. Endlich kann der Minister jetzt solche Stellen, wo die Einrichtung der Turbinen einem passenden Prozentsatz der abwärtswandernden Fische gefahrlose Durchwanderung verbürgt, grössere Gitteröffnungen (bis auf 80 mm) gestatten.

Aber wenn auch das Turbinengitter sich an der denkbar besten Stelle befindet, können Zufälle eintreten, in denen sein Nutzen illusorisch wird. An verschiedenen Stellen gibt es sozusagen kein Freiwasser, ausgenommen vielleicht im Herbst und Winter. In der ganzen Zeit, in der Lachs- und Forellenjungfische in normaler Weise abwärts ziehen (Frühjahr bis in den Sommer hinein) wird alles Wasser gebraucht, alles geht durch die Turbine; es ist kaum wahrscheinlich, dass die Jungfische ohne Schaden zu nehmen so lange oberhalb der Turbine stehen bleiben können, bis schliesslich im Herbst Freiwasser gegeben wird, oder bis die feinen (20 mm) Gitter von Anfang Oktober an eventuell herausgenommen werden. Viele Jungfische werden in der Wartezeit Beute von Raubfischen, Vögeln und Knaben, andere folgen wahrscheinlich freiwillig der Strömung und enden am Turbinengitter, andere wieder verlieren vielleicht den Wandertrieb und werden zu Bachforellen. In der Praxis wird es wohl meistens so kommen, dass der Fisch nach einigem Suchen ein Loch im Gitter findet, durch das er sich hindurchwindet: Nun bleibt noch die Frage, ob er ohne Schaden die Turbine passieren kann.

Bei den zwei untersuchten Flüssen, Sneum Aa und Kongeaa, liegen folgende Wasserkraftanlagen:

1. Sneum Aa.
   a. Hauptlauf: Faaborg Mühle, Endrup Mühle.
   b. Terpling Aa: Tvilho Mühle (am Zulauf Nörrebäk), Bolding Elektrizitätswerk.
   c. Holsted Aa: Hulkjär Mühle, Holsted Mühle, Gjörklint Mühle, Gjörding Elektrizitätswerk, Bramminge Hovedgaard (Elektrizitätswerk).

2. Kongeaa.
   a. Hauptlauf: Knagemühle, Jedsted Mühle.
   b. Gjesten Aa: Gjesten Mühle.
   c. Vejen Aa: Vejen grosse und Vejen kleine Mühle.
   d. Maltbäk: Sönderskov Mühle.
   e. Nielsbygaard Möllebäk: Nielsbygaard Mühle.

Die Untersuchung ergab, dass von diesen 16 Wasserkraftanlagen Tvilho Mühle, Knage-, Gjesten-, Vejen kleine-, Sönderskov- und Nielsbygaard Mühle für die Frage der Möglichkeit einer Abwärtswanderung der Jungfische von untergeordeneter Bedeutung waren, entweder weil die betreffenden Wasserläufe sich schlecht für Forellenbrut eignen, oder weil die erwähnten Mühlen in ihrem derzeitigen Zustande kein wesentliches Hindernis für den Abwärtszug der Fische bilden.

Von den übrigen 10 Anlagen bieten natürlich das Hauptinteresse die unteren, durch welche die Hauptmasse der abwärtswandernden Jungfische ziehen muss.

Bei der Beurteilung der Bedeutung einer Turbinenanlage für die Jungfische des Hinterlandes kommt folgendes in Betracht:

1. Ist Freiwasser in der Zeit der Abwärtswanderung vorhanden und in welchem Umfange?
2. Welchen Möglichkeiten sind die in die Turbine gekommenen Fische ausgesetzt?

Leider lässt sich kaum mit Sicherheit feststellen, inwiefern die abwärtswandernden Jungfische ohne Rücksicht auf die Tageszeiten ziehen, ob sie vorzugsweise in der Nacht oder am Tage wandern. Für die Bevorzugung der Nachtwanderung besteht eine gewisse Wahrscheinlichkeit (einige Kleinforellen wurden in Aalkisten, die nur nachts vom Wasser durchspült waren, gefangen), mehr kann jedoch hierüber vorläufig nicht gesagt werden.

Es würde — trotz der Aalkisten — sicher von Vorteil sein, wenn die Wanderung vorzugsweise in der Nacht stattfände, weil sich dann den Fischen eine grössere Möglichkeit bieten würde, mit dem Freiwasser an den Werken vorbeizukommen; die Aalkisten könnten übrigens ohne Schwierigkeit so eingerichtet werden, dass die Jungfische ohne Schaden zu nehmen ausgesetzt werden können.

Die bei den zwei Flüssen vorhandenen Turbinen waren von sehr verschiedener Konstruktion und Grösse, ihre Kraft wechselte von ein Paar Pferdekräften bis zu 100 Pferdekräften. Die Leute der dortigen Gegend waren verschiedener Meinung darüber, was unbeschädigt die Turbinen passieren könne; einige meinten, dass jeder Fisch zerquetscht werden müsse, andere wieder, dass die meisten (freilich nicht zu grosse) ohne weiteres durchkommen könnten, ja an einer Stelle wurde sogar behauptet, dass ein Hund unverletzt durch eine der grösseren Turbinen gekommen sei. Zuverlässige Beobachtungen über den Zustand der Fische konnten jedoch nicht in grösserem Masse gewonnen werden; nur darin war man sich ziemlich einig, dass die Turbine der Holsted Mühle zahlreiche Fische vernichte.

Im Auslande sind mehrere Male Versuche angestellt, die Wirkung der Turbinen auf die Fischwanderung zu erklären. Sowohl Johs. Lundbeck wie Gunnar Alm und W. Schmassmann haben in letzter Zeit solche angestellt, und aus früherer Zeit (1899) sind auch einige schweizerische Versuche vorhanden, wie Schmassmann erwähnt. Es ist hierdurch festgestellt, dass Fische, ohne durch die plötzliche Druckveränderung Schaden zu nehmen, die Turbinen passierten, und dass auch ein Teil der Fische durch die Turbinen gelangte, ohne überhaupt verletzt zu werden. Aber bei sämtlichen Versuchen bestand die Schwierigkeit, alle Versuchsfische wieder einzufangen, deshalb konnte man keine einwandfreie Berechnung darüber aufstellen, wie gross der Prozentsatz der unbeschädigten Fische und wie gross derjenige der beschädigten war. Nur bei den von Schmassmann angestellten Versuchen mit einer kleinen Turbine von 5 Pferdekräften wurden alle, oder doch jedenfalls die meisten Versuchsfische wieder gefangen; die anderen Versuche wurden mit grossen Turbinen gemacht: Augst (2500 Pf., beim Versuch jedoch nur 1700 Pf.); Friedland (4 Zwillingsturbinen, jede mit 36 cbm/sek. Wasserverbrauch); Lille Edet (Grösse des Saugrohrs 7,5×14,4 m), hierbei ergaben sich grosse Schwierigkeiten hinsichtlich eines rationellen Versuches. Soviel ist jedoch bereits mit Sicherheit festgestellt, dass bei einigen Versuchen eine erhebliche Anzahl Fische in unbeschädigtem Zustande durch die Turbinen kamen, während bei anderen Versuchen eine grosse Anzahl beschädigt wurden. Hieraus folgt, dass eine allgemein gültige Regel über den durch Turbinen verursachten Schaden kaum aufgestellt werden kann — man kann sich nur von Fall zu Fall ein Urteil bilden.

Da es einem Nicht-Techniker ziemlich schwer fallen dürfte, sich ein Urteil zu bilden über die Konstruktion einer Turbine, ihre Wirkungsart und infolgedessen über die Möglichkeit einer ungehinderten Passage für die Fische, soweit sie die verschiedenen Turbinenkonstruktionen

gestatten, so möge hier auf die instruktive Beschreibung von älteren und neueren Turbineneinrichtungen, wie sie LUNDBECK in seiner Abhandlung gibt, hingewiesen werden. Glücklicherweise scheinen die neueren Turbinensysteme den Fischen den ungehinderten Durchgang bei weitem besser zu ermöglichen, als die älteren Bauarten, aber ausser dem Konstruktionstyp selbst spielen natürlich die Grössenverhältnisse der Turbine, die Durchlaufsgeschwindigkeit des Wassers und die Umdrehungsgeschwindigkeit des Laufrades eine Rolle; ferner ist selbstverständlich die Länge des Fisches von grosser Bedeutung; Aale werden deshalb immer viel grössere Schwierigkeiten beim Durchgang haben als Lachs- und Forellenjungfische, die nur ausnahmsweise über 20 cm lang, in der Regel aber unter 15 cm sind. Um aber auf einer praktisch brauchbaren Grundlage aufbauen zu können, bedarf es bei weitem zahlreicherer Versuche und zwar mit Turbinen von verschiedenem Typ.

Fig. 1. Eine Zeichnung des angewandten Reusenbeutels.

Um nun den Anfang mit einer solchen individuellen Untersuchung unserer Turbinen zu machen, wurden drei ausgewählt, die den Vorteil boten, 1) dass sie klein waren, so dass die Arbeit durch den Wasserdruck nicht zu sehr behindert wurde, was auch den Vorteil hatte, dass sie sich bei dem Versuch ohne grössere Schwierigkeit stoppen und wieder in Gang bringen liessen, 2) dass durch die lotrechte Stellung des Saugrohres die Anbringung eines Fangbeutels erleichtert wurde, und 3) dass die Saugrohre gleichen Durchmesser hatten, weshalb bei den Versuchen derselbe Fangbeutel an allen drei Stellen benutzt werden konnte.

Die Versuche selbst wurden auf folgende Weise ausgeführt: Ein starker Netzbeutel (Fig. 1) wurde am unteren Ende des Saugrohrs befestigt. Der Netzbeutel, der zu dem Zwecke aus Garneelennetz gemacht und durch zwei spanische Rohrstockreifen gespannt gehalten wurde, hatte eine Kehle und war an beiden Enden mit losen Schnüren versehen, um am hinteren Ende das Schliessen des Beutels und am vorderen das Festschnüren an das Saugrohr zu ermöglichen. Damit ein Fortspülen des Beutels durch das Turbinenwasser verhindert werde, wurden Stricke vom oberen Rande des Beutels nach feststehenden Balken oder anderen Stützpunkten hin gezogen, wenn solche zufällig oberhalb des Beutels zur Verfügung standen. Während das Festknüpfen vor sich ging, war die Turbine zum Stehen gebracht.

Dann wurden über die wieder in Gang gesetzte Turbine eine Anzahl Versuchsfische ausgeschüttet. Kurz darauf wurde die Turbine wieder angehalten, der Beutel vom Saugrohr losgebunden und der Fang untersucht.

Indessen zeigten sich bei der Durchführung der Versuche einige Schwierigkeiten, wie sie bereits aus den oben besprochenen Versuchen im Auslande bekannt sind. Der Beutel war praktisch genug; er liess sich genügend fest binden, beim Abbinden entschlüpfte ihm kein Fisch, wenn man ihn auch notwendigerweise wegen des geringen Platzes unter den Saugrohren sehr kurz machen musste. Alle Fische, die durch die Turbinen gingen, wurde ohne Zweifel gefangen und beobachtet. Ob etwas (ganze Fische oder Teile) in den Turbinen sitzen blieb, kann nicht gesagt werden, viel war es aber gewiss nicht; in dem lotrechten Saugrohr konnten jedenfalls Fische nicht stehen bleiben, dadurch wurde die Schwierigkeit behoben, die sich bei mehreren ausländischen Versuchen einstellte, dass sich nämlich Fische in den Auslaufkanälen der Turbinen aufhalten konnten. Hingegen war es nicht leicht, die Fische während der Versuche in die Turbinen hinein zu bekommen, eine Schwierigkeit, die sich auch bei den ausländischen Versuchen geltend machte, die aber sicher bei den dänischen grösser war, da die Stärke des Wasserzulaufs zu diesen kleinen Turbinen nicht genügte, um zu verhindern, dass die Fische die Saugkraft überwinden und nach oben gegen die Strömung flüchten konnten.

Da der erste Versuch die Möglichkeit eines solchen Mangels deutlich gezeigt hatte, machte man bei den übrigen Versuchen die Probe, die Fische durch einen Blechtrichter hinunterzuschütten, wobei der Trichter über eine der Spalten zwischen den Leitschaufeln gesetzt war. In dem einen Fall, wo die Turbine hoch lag, war kein genügender Druck auf den Fischen, wenn sie in den Trichter geschüttet waren, viele von ihnen entkamen gegen die Strömung. In dem andern Falle lag die Turbine am Grunde der Turbinenkammer, so dass man sich einer längeren Trichters bedienen musste; dadurch kamen die Fische beim Einschütten in den Trichter unter grösseren Druck, und vermutlich wurden sie sofort in die Turbine hineingesogen; von hier entkam nur ein Paar.

Auch die dänischen Versuche sind somit nicht glatt verlaufen. Je mehr Erfahrungen gesammelt werden in Bezug auf die Fehlermöglichkeiten bei den Versuchen und Methoden zur Vermeidung der Übelstände, desto schneller wird es glücken, praktische Verfahren einzuführen. Trotz der Fehler wurde übrigens auf Grund der dänischen Versuche ein klares Ergebnis erzielt, wie unten gezeigt wird.

Als Versuchsfische wurden in allen drei Fällen Regenbogenforellen

von etwa 10 cm—20 cm Länge aus verschiedenen Forellenzuchtanlagen (Hjortkjär, Vejen grosse Mühle und Hulkjär Mühle) gebraucht. Diese Fische entsprechen so ziemlich, was Grösse, Form und Bewegungsart betrifft, genau den abwärts wandernden Lachs- und Forellenjungfischen; allerdings war die durchschnittliche Länge der Versuchsfische ein wenig grösser als die der abwärtswandernden Jungfische.

Über die einzelnen Versuche kann folgendes mitgeteilt werden:

1. Bolding Elektrizitätswerk (Versuch vom 6—IX—1930).

Figur 2 zeigt schematisch das Gebäude, die Turbinenkammer und das aus ihr hervorragende Saugrohr. An der linken Seite des Kanals führt eine Holzrinne hinaus über das Hinterwasser; sie dient als Frei-

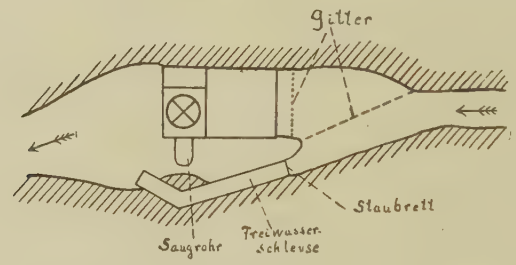

Fig. 2. Schematischer Grundriss vom Bolding Elektrizitätswerk.

wasserschleuse. Auf Fig. 3 finden sich dieselben Einrichtungen; das Wasser fällt in einem Strahl aus der Freiwasserrinne hinunter in das Hinterwasser. Die Fallhöhe beträgt 2,8 m. Das Saugrohr ist lotrecht nach unten gebogen; sein Durchmesser ist ungefähr 70 cm, unter ihm ist nur wenig Platz. Die Turbine ist vom System Mahler; ihr Durchmesser ist etwa $^3/_4$ m. Die Öffnung zwischen den völlig geöffneten Leitschaufeln beträgt etwa 18 cm. Bei voller Belastung hat die Turbine 24 Pferdekräfte und macht 140 Umdrehungen in der Minute.

Aus der Teichwirtschaft „Hjortkjär" wurden 40 Regenbogenforellen von 10—15 cm und 40 von 15—20 cm mitgebracht. Nachdem die Turbine durch Herablassen der Schutzbretter zum Stehen gebracht und der Reusenbeutel an das untere Ende des Saugrohrs gebunden war, wurde sie wieder in Gang gesetzt; hierauf wurden die 40 kleineren Fische gerade über die nach oben gerichteten Öffnungen zwischen den Leitschaufeln hinuntergeschüttet, sofort wurden dann die Schutzbretter wieder heruntergelassen. Bei der Sichtung des Beutels zeigte es sich, dass nur 9 Fische wiedergefangen waren; die anderen 31 waren nicht durch die Turbine gegangen, sie müssen ihren Weg nach oben gegen den Strom

genommen haben. Die wiedergefangenen 9 waren alle unbeschädigt und lebenskräftig.

Der Beutel wurde wieder aufgebunden, die Schutzbretter hochgezogen. Darauf wurden die 40 grösseren Fische über die Turbine geschüttet; diese

Fig. 3. Bolding Elektrizitätswerk gesehen vom Hinterwasser. Aus der undichten Freiwasserschleuse fällt ein Wasserstrahl nieder in das Hinterwasser. Gerade links vom Strahl sieht man das gekrümmte Saugrohr.

wurde 5 Minuten lang in Gang gehalten, um die Fische zu ermüden, so dass sie von der Turbine eingesogen werden und durch dieselbe gehen konnten. Das gelang einigermassen, da sich bei der Sichtung des Beutels 33 Fische vorfanden (von diesen gehörten freilich 2 zu dem ersten, kleineren Satz). Alle 33 Fische waren wohlbehalten, kein einziger war gestossen oder verwundet, nur bei 10 Stück fanden sich auf der einen Seite der Körpermitte geringfügige Schuppenschürfungen.

Fig. 4. Grosse Mühle von Vejen. Über die Vejen Aa führt eine Fahrbrücke mit Geländer. Unter der Brücke ist ein Stauwerk; zwischen diesem und der Brücke schimmert das Oberwasser hervor. Ein kleiner Wasserstrahl drängt sich durch eine Ritze zwischen den Staubrettern, rechts hiervon eine Aalkiste, links die Turbinenschleuse.

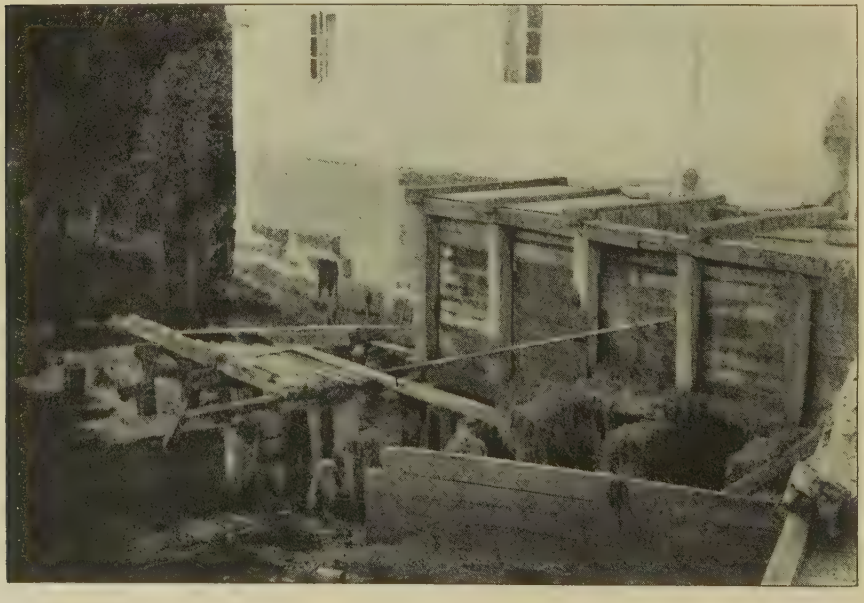

Fig. 5. Die Turbinenschleuse gesehen von der Brücke oberhalb der Aalkiste. Die Turbinenkammer ist zugedeckt (hierauf liegen einige zufällige Geräte). Zahlreiche alte Pfähle im Hinterwasser, teilweise mit Wasserpflanzen von einer Flussräumung herrührend behangen. Am Ende der Turbinenkammer sieht man die Spitze eines Stosshebers, der durch das schräge Rohr an der Seite der Turbinenschleuse Wasser bekommt.

Anscheinend ist diese Turbine also für die Fische unschädlich. Aber möglicherweise ist ein Fehler bei dem Versuch eingetreten. Man könnte sich denken, dass die Fische erst durch die Turbine gegangen sind, als die Kammer nach Herunterlassen der Schutzbretter anfing leer zu laufen, — also in dem Augenblick, wo die Umdrehungsgeschwindigkeit gering war. Wahrscheinlich ist das jedoch nicht und vor allem ist kaum anzunehmen, dass alle Fische so lange gewartet haben sollten.

2. Vejen grosse Mühle (Versuch vom 8—IX—1930.)

Auf Fig. 4 sieht man die Stauvorrichtung bei der grossen Mühle von Vejen; sie ist in Verbindung mit einer Fahrbrücke über die Vejen Aa angebracht; längs der Brücke befindet sich ein Geländer. Das Oberwasser ist unter der Brücke zu sehen. Ein wenig Wasser kommt durch eine Ritze zwischen den Schleusenbrettern. Rechts hiervon sieht man eine Aalkiste; die lange Schleuse, die gestützt durch Pfahlwerk sich ein paar Meter an der Seite des grauen Gebäudes hinzieht, ist eine Wasserkraftschleuse; der äussere Teil ist eine Turbinenkammer. Auf Fig. 5 sieht man alles aus der Nähe, da die Photographie von der Brücke oberhalb der Aalkiste aufgenommen ist. Auf der Turbinenkammer selbst liegt ein Deckel; die Kammer ruht auf Pfählen (ausserdem befinden sich eine Menge alter Pfähle im Hinterwasser), und zwischen diesen hindurch geht das Saugrohr (unsichtbar) senkrecht nach unten. Die Turbine hat 15 Pferdekräfte, der Durchmesser des Saugrohrs ist etwa 60 cm, die Fallhöhe ungefähr 2 m. Unter dem unteren Rande des Saugrohres befindet sich etwa 70 cm Wasser.

Zuerst wurde das Mass genommen für einen Blechtrichter, durch welchen die Fische gerade hinunter zwischen die Leitschaufeln der Turbine geschüttet werden sollten. Sobald der Trichter hergestellt war und 50 Regenbogenforellen von 10—15 cm und 50 von 15—20 cm zur Stelle waren, wurde der Beutel am Saugrohr befestigt und das Schutzbrett hochgezogen. Der Trichter wurde in Stellung gebracht und die kleineren Fische hineingeschüttet. Gegen alle Erwartung machte man die Wahrnehmung, dass zahlreiche Fische aus dem unteren Ende des Trichters entschlüpften; die Saugkraft war so schwach, dass die Fische nicht mitgerissen wurden.

Die Turbine wurde darauf 5 Minuten lang in Gang gehalten, um die entwichenen Fische zu ermüden und sie hinunterzusaugen. Bei Sichtung des Beutels fanden sich nur 40 Fische. Von diesen waren 24 lebenskräftig (ein Teil mit geringeren Schuppenschürfungen), 16 jedoch waren tot oder stark beschädigt; 9 hiervon waren in zwei Teile zerstückelt, während die 7 Spuren von kräftigen Schlägen trugen.

Der Reusenbeutel wurde wieder festgebunden und der Versuch mit dem Satz der grösseren Fische wiederholt. Wiederum entkamen zahlreiche Fische durch das untere Ende des Trichters, obgleich er nun der Öffnung zwischen den Schaufeln besser angepasst war. Die Turbine wurde dann 5 Minuten in Gang gehalten. Bei der Sichtung fanden sich 37 Fische, von denen 19 lebenskräftig (ein Teil mit Schuppenschürfungen), 9 in zwei Teile zerstückelt und 9 stark gestossen waren, 13 wurden ver-

Fig. 6. Regenbogenforellen, beschädigt durch die Turbine der Hulkjär Mühle. Keine ist zerstückelt, und keine hat zwei Schlagmerkmale.

misst. In Wirklichkeit waren jedoch mehrere der grösseren (und kräftigeren) Fische aufwärts gegen die Strömung verschwunden, denn einige der nun wiedergefangenen Fische stammten offenbar aus dem ersten Satz.

Das Gesamtergebnis war: ausgesetzt 100 Fische, wiedergefangen 77, hiervon 43 lebenskräftig, tot oder tötlich verletzt 34. Möglicherweise sitzen einige der vermissten 23 Fische fest in der Turbine, die meisten aber haben sich nach oben gegen die Strömung gerettet.

3. **Hulkjär Mühle** (Versuch vom 9—IX—1930).

Die Zuleitung des Wassers geschieht hier durch eine Rohrleitung mit einem Durchmesser von 47 cm. Die Turbine ist in anderer Weise als in den zwei oben besprochenen Fällen eingebaut. Sie hat nämlich

ein wagerechtes Laufrad und liegt am Boden einer ziemlich tiefen Turbinenkammer, so dass sie nur ein sehr kurzes (kaum $^1/_2$ m langes) Saugrohr hat. Die Fallhöhe ist 2,1 m. Die Turbine ist vom System Mahler von ca. 1890, jedoch ein wenig umgebaut; der Durchmesser des Laufrades beträgt 40 cm; 10 Laufradschaufeln. Der Zwischenraum zwischen den Leitschaufeln, wenn sie ganz geöffnet sind, ist 9 cm. Die Turbine hat nur 1,5 Pferdekräfte und macht 160 Umdrehungen in der Minute. Der Durchmesser des Saugrohrs beträgt etwa 70 cm.

In der ausgeleerten Turbinenkammer wurden zwei Stangen quer befestigt, und zwischen ihnen wurde ein langer Blechtrichter festgeklemmt; der untere Teil des Trichters war umgebogen und führte gerade hin zur Öffnung zwischen den Schaufeln.

Im Hinterwasser war der Zugang zum Saugrohr schwierig. Mein Gehilfe musste sich ausziehen und in liegender Stellung unter dem Boden der Turbinenkammer arbeiten. Die Arbeit war so beschwerlich, dass wir uns mit einem einzigen Versuch begnügen mussten, bei dem 50 Regenbogenforellen von 10—15 cm und 50 von 15—20 cm alle durch den Trichter geschüttet wurden, nachdem die Turbine wieder in Gang gesetzt war. Das Schutzbrett wurde sofort heruntergelassen, aber es dauerte einige Zeit, bis die Turbinenkammer geleert war. Bei der Sichtung des Beutels zeigte es sich, dass der Wiederfang ausgezeichnet war, es fehlten nur 2 Fische. Von den 98 Fischen waren 52 lebenskräftig, während 46 verletzt waren, keiner von diesen zerstückelt (Fig. 6). Von den 52 wohlbehaltenen waren die meisten aus dem kleinen Satz (augenscheinlich 39 kleiner als 15 cm und 13 grösser als 15 cm).

Möglicherweise verschiebt sich der Prozentsatz von beschädigten Fischen durch die Zuführung in die Turbine durch so enggebaute Trichter, wie diese kleinen Turbinen sie erfordern. Die Fische gelangen vielleicht in die Turbine in einer anderen Lage, als wenn sie frei aus der Turbinenkammer gekommen wären.

Zwei Turbinen verursachten eine Sterblichkeit bei den passierenden Fischen von 10—20 cm von 44 % (Vejen grosse Mühle), bzw. 47 % (Hulkjär Mühle), während die dritte (Bolding Elektrizitätswerk) ganz unschädlich zu sein schien. Es steht ausser Zweifel, dass die kleinsten Fische am besten davon kamen.

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Reviews.

W. R. G. Atkins. Seasonal Variations in the Phosphate and Silicate Content of Sea-Water in Relation to the Phytoplankton Crop. Pt. V. November 1927 to April 1929, compared with earlier years. Journ. Mar. Biol. Assoc., N. S., Vol. XVI, No. 3. Plymouth, 1930.

Schon die früheren Untersuchungen von Atkins und Mitarbeitern (seit 1923) haben gezeigt, dass Phytoplankton- und Nährstoffgehalt (Phosphat, Nitrat, Silicat) etwa folgenden jährlichen Verlauf nehmen: In dem während des ganzen Winters nährstoffreichen, planktonarmen Wasser findet im Frühling eine plötzliche starke Planktonentwicklung statt, während gleichzeitig ebenso plötzlich der Nährstoffgehalt sinkt und Nährstoffmangel bald der Entwicklung ein Ende macht. Teils aus dem abgestorbenen Plankton, teils durch vertikale Mischung mit tieferen Schichten wird neuer Nährstoff zugeführt und neues Planktonleben kann entstehen; so wechseln Planktonwucherungen und Nährstoffregeneration noch oft während des Sommers, ohne dass jedoch annähernd wieder die Stärke der Frühjahrswucherung erreicht würde. Erst im Herbst setzt meistens noch einmal eine stärkere Entwicklung ein, auf die dann das Wintersterben folgt, das die ganzen Nährstoffmassen frei werden lässt und den Phosphat-, Nitrat- und Silikat-Gehalt des Wassers wieder auf das höchste Niveau bringt.

Das ist der allgemeine Typus des jährlichen Verlaufes. Im Einzelnen, wie in der Häufigkeit, der Intensität und Dauer der Produktionswellen können beträchtliche Unterschiede zwischen den Jahren auftreten; besonders aber findet das Einsetzen der ersten Frühjahrswucherung zu sehr verschiedenen Zeiten statt, die bis 6—7 Wochen auseinanderliegen können. Die Planktonproduktion ist nun von grösstem Einfluss auf das Gedeihen der Fischbrut und sie bedingt deshalb auch mit die Verschiedenheit der Fischjahrgänge. Der Termin der Frühjahrswucherung kann nicht von dem Nährstoffgehalt des Wassers abhängen; Nährstoff ist ja in der Zeit im Überfluss vorhanden. Auch mit der Temperatur konnte man keine Beziehung entdecken. So bleibt noch die Wirkung des Lichts zu verfolgen.

Atkins hat für eine Reihe von Jahren den Verlauf der Beleuchtung in dem untersuchten Gebiet festgestellt (zuletzt auch photometrisch registriert) und mit den übrigen Resultaten verglichen. Danach scheint tatsächlich das Einsetzen der Planktonentwicklung im Frühjahr sehr von der Intensität der Beleuchtung abzuhängen. Bei der Kalkulierung der wirksamen Beleuchtung ist zu berücksichtigen, dass sie sich aus zwei Bestandteilen zusammensetzt: 1) dem direkten Sonnenlicht, dessen Wirkung sehr von der Sonnenhöhe abhängt, vor allem in den tieferen Wasserschich-

ten. Nur wenn man dieselben Monate vergleicht, kann man die meteorologische Sonnenscheindauer als Mass für die Wirkung des direkten Sonnenlichts einsetzen; 2) dem diffusen Tageslicht, dessen Wirkung durchschnittlich die Hälfte des Sonnenlichts beträgt. Sein Mass ist die Tageslänge.

Um die mittlere monatliche Gesamtwirkung der Beleuchtung zu bekommen, addiert man zu der mittleren monatlichen Tageslänge das zweifache der mittleren monatlichen Sonnenscheindauer. Diesen Wert nennt Atkins die mittlere »wirksame Tageslänge« des betreffenden Monats und er findet, dass im allgemeinen, wenn schon früh hohe wirksame Tageslängen erreicht werden, auch früh die starke Phytoplanktonwucherung stattfindet.

Es müssen aber auch lokale Ursachen den Termin und die Intensität des Frühjahrswachstums beeinflussen, denn dieses setzt nicht an allen Stationen zugleich ein. Solche Einflüsse können nicht von der Küste oder Flüssen stammen. Es kann nämlich ebensogut die Planktonwucherung an einer landferneren Station beginnen wie an einer landnäheren. Ausserdem ist Flusswasser meistens viel ärmer an Phosphat und Nitrat als Meerwasser im Winter und Vorfrühling; Silikat ist zwar reichlicher vorhanden, wird aber überhaupt wohl nie Minimumfaktor für das Plankton.

Die photometrische Lichtregistrierung mit der Kaliumzelle in verschiedenen Tiefen zeigen, wie ausserordentlich wechselnd die Lichtdurchlässigkeit des Wassers sein kann, wenn Trübungen durch Plankton auftreten. Die Durchlässigkeit kann bis auf $^1/_8$ vermindert werden. Die Lichtmengen, die den unteren Schichten zugeführt werden, können dadurch ebenso stark wie z. B. durch die Unterschiede zwischen Sommer und Winter verändert werden.

Die für das Plankton günstigste Beleuchtung liegt nicht immer in den obersten Schichten, da hier im Hochsommer das Licht oft so intensiv ist, dass das Wachstum geschädigt wird und Regeneration von freiem Nährstoff eintritt. Für die Untersuchung der jährlichen Schwankungen wurde deshalb die 5 m-Tiefe gewählt.

Die Hauptstätten der Regeneration sind Tiefen- und Bodenwasser, wo auch während des Sommers Rückbildung von Nährstoff stattfindet, der langsam wieder den durchlichteten und planktonreichen Oberschichten zugeführt wird. Er wird aber so schnell verbraucht, dass freier Nährstoff im Sommer die Oberfläche nicht erreicht.

Für alle diese Folgerungen wurde die Grösse der Phytoplanktonproduktion aus dem Phosphatverbrauch berechnet, d. h. aus der Abnahme des Phosphatgehalts an zwei aufeinander folgenden Beobachtungsterminen. Regeneration entspricht dann umgekehrt Phosphatzunahme. Produktion und Regeneration folgen sich in oft sehr kurzen Abständen. Wie kurz diese Abstände sind, hängt offenbar z. T. vom zeitlichen Abstand der Beobachtungstermine ab, denn 1928, wo besonders häufig beobachtet wurde, sind diese Abstände besonders klein. Man kann also die Termine garnicht eng genug legen.

Das Silikat wird im Gegensatz zum Phosphat scheinbar nie begrenzender Faktor. Die Silikatgehalte sind stets viel höher als die Phosphatgehalte. So ist das mittlere Maximum an der internationalen Station E1 (Mitte der Kanalmündung) für P_2O_5 etwa 35 mg/m³, für SiO_2 2—300 mg/m³

(Mitte Winter) und das Minimum < 1 mg P_2O_5/m^3 und 33 mg SiO_2/m^3 (Mitte Sommer). Der jährliche Gang dieser beiden Faktoren ist sehr ähnlich, nur setzt der Frühlingsabfall des Silikats etwas früher ein als der des Phosphats. Es mag das damit zusammenhängen, dass zuerst die Diatomeen anfangen zu wuchern. Die Gesamtkohlensäure zeigt denselben jährlichen Gang, aber die Ausschläge sind naturgemäss viel geringer.

Die Methoden zur Bestimmung von Phosphat und Silikat wurden weiter verbessert. Es wurde ein exakteres Verfahren angewandt, um sehr kleine Phosphatkonzentrationen zu bestimmen, denn es interessiert ja besonders festzustellen, wie weit das Plankton dem Wasser den Nährstoff entziehen kann. Bei der Silikatbestimmung wird auf eine Fehlerquelle hingewiesen, die in der als Standard verwendeten Pikrinsäure liegen kann, wenn diese nicht ganz rein ist. Da die früheren Beobachtungen mit einem Faktor berechnet waren, der mit einer offenbar unreinen Substanz ermittelt war, so sind die früheren Resultate entsprechend umzurechnen (mit 1,3 zu multiplizieren).

Von grösster Wichtigkeit für die Möglichkeit, Schlüsse aus den Termin Beobachtungen zu ziehen, ist es, dass die Ereignisse in einem geschlossenen System vor sich gehen, dass man also den jährlichen Ablauf als einen Kreisprozess betrachten kann. In der Hinsicht ist nun die Beobachtungsstation Atkins' in der Mitte des Kanals besonders günstig, denn nach den Untersuchungen von Harvey ist dort kein wesentlicher Durchstrom vorhanden. Man beobachtet also immer Vorgänge innerhalb derselben Wassermasse. Es ist deshalb besonders zu begrüssen, dass dort diese Untersuchungen so umfassend über lange Zeit hin durchgeführt werden. Man darf vielleicht wünschen, dass sie noch weiter, z. B. nach der Seite der quantitativen Planktonforschung hin, ausgebaut werden. H. Wattenberg.

C. E. P. Brooks. The Rôle of the Oceans in the Weather of Western Europe. Quart. Journ. Roy. Met. Soc., Vol. LVI, No. 234. London, 1930.

The author discusses first the effect of changes of the speed of the surface currents in the Atlantic Ocean, which are caused by changes of the atmospheric circulation. He points out that an increase of the trade winds must be expected to be followed by higher surface temperatures in the North Atlantic and finds this conclusion supported by the observations. An interesting difference is shown between the effects of the NE. trade wind and the SE. trade wind. The NE. trade wind has only a small supply of warm water available for transportation and when this is exhausted its place is taken by cold upwelling water. An initial temperature increase of the surface temperature of the North Atlantic is, therefore, soon followed by a temperature decrease. The SE. trade wind has, on the other hand, a much greater volume of warm water at disposal for transportation and strong SE. trade winds are, therefore, followed by high temperatures in the North Atlantic for a long period. These high temperatures effect in turn the meteorological conditions in western Europe.

Changes in the cold currents of the North Atlantic, especially the Labrador current, which are caused by changes in the atmospheric circulation,

are also as a rule followed by corresponding changes in the weather of western Europe, but the whole system is so complicated that definite relations can be established in only a few cases.

A surprising result of the author's investigations is that an accumulation of ice in the Kara Sea, Barents Sea and Greenland Sea in one season appears to influence the pressure distribution over the north-eastern North Atlantic for a period of four years. The author attributes this remarkable relation to the persistence of the main masses of ice in the central Arctic Ocean, drawing attention to the fact that ice which is formed at the Siberian Coast takes about four years to cross the Arctic Ocean. The writer cannot quite follow the reasoning of the author, because the mass of ice in the central Arctic Ocean must be assumed to remain practically constant and the variations to occur at the fringes only.

H. U. Sverdrup.

A. Defant. Einführung in die Geophysik. Teil 3. Dynamische Ozeanographie. J. Springer, Berlin, 1929.

Professor Defant's book is a treatise on Physical Oceanography and not on hydrodynamics, but given a knowledge of the fundamental equations of the latter, such as can be obtained from the easier textbooks, it is not difficult reading and should be welcome to every oceanographer. The literature of the subject is very scattered and the author has done his science a service in bringing its chief results together.

The earlier parts deal with the fields of gravitation and pressure in the sea and their practical computation from observations of temperature and salinity. The author follows established oceanographic custom in making use of the dynamic metre; there is no doubt as to the convenience of this quantity and the opposition which it has aroused is largely due to its rather unfortunate name. This section could have been expanded with advantage. Then follows an account of the internal and external forces which can set up or modify currents in the sea, and the fundamental equations of hydrodynamics are given. The third and fourth sections are given to the statics and dynamics of the sea and the fifth to the general dynamics of ocean currents. This latter is the longest in the book. The first nine pages deal with the currents in a frictionless homogeneous sea affected by the earths rotation. Then follows a short account of the effects of friction. The larger part of the section deals with currents which as in nature are affected by friction and external forces, but are still ideal in that the water is assumed to be homogeneous; it is founded chiefly on the classical work of V. W. Ekman. A short description is given of turbulence and the phenomena of mixing, phenomena which have attracted considerable attention recently. The stratified sea which is found in nature is discussed in section six and the circulation theory of V. Bjerknes and its practical application by Helland-Hansen and Sandström in section seven. Professor Defant holds that the chief cause of the horizontal currents is the wind, though he does not overlook the importance of differences of density in the case of the vertical circulation. In discussing the general circulation he applies to the oceans terms borrowed from meteorology,

such as troposphere, stratosphere and polar front. It is doubtful whether he is justified in stretching the analogy so far. The remainder of the book is devoted to the subjects of wave motion and the tides, both of which, the latter in particular, have been treated at length elsewhere. The author therefore omits all description of the equilibrium and dynamical theories of the tides and confines himself to special subjects such as the tides of channels and enclosed seas and the influence of tidal friction.

The book should be of value both to the beginner and to the expert who wishes to know shortly what has been done in a particular line and who did it. It is to be hoped that it will be translated into English; if this is done there are some misprints in the tabular work and among the mathematical symbols which should be corrected. D. J. M.

J. Johnstone, R. J. Daniel, and H. M. Lewis; in Report for 1929 on the Lancashire Sea-Fisheries Laboratory. No. XXXVIII. Liverpool, 1930.

Commenting on the hydrographical matter contained in the report, Professor Johnstone states that such hydrographic investigations as these under review were originally intended to have prospective application, it being thought that their results would enable one to predict important events, such as the productivity of fishery seasons, and to work out relationships between hydrographic phenomena and weather.

By studying the vagaries of the Atlantic Drift, it may become possible to forecast weather, and the pulse of the Atlantic Drift can be felt in the North Sea, the Channel etc. Such data as have been collected under the scheme of investigation put in practice by the International Council for the Exploration of the Sea, will enable meteorologists to establish relations between hydrographic and weather conditions, but Professor Johnstone considers that present scale hydrographic research cannot suffice to produce results that can be applied to forecasting weather. The reviewer may here recall that Professor Johnstone's paper of three years ago in the »Knipowitsch Festschrift« dealt with this subject of weather forecasting *via* the consideration of hydrographic phenomena.

Speaking of Dr. Daniel's salinity observations, Professor Johnstone refers to the "error" of sampling on consecutive days. Actual differences of salinity of as much as 0.5 $^0/_{00}$ at the same place on consecutive days are on record, whilst on two out of every three pairs of samplings on successive days at the same place, a difference of 0.15 $^0/_{00}$, or less, is to be expected. Such differences have, it may be recalled, been earlier termed "accidental differences" by Dr. Johnstone, and reference to the paper just mentioned (Moscow 1927) could, in the reviewer's opinion, profitably be made by any reader who desires fuller consideration of these matters. Heterogeneity of the water, such as causes the fortuitous salinity differences, can be explained, Professor Johnstone holds, by considering the complicated mixing effects due in the main to the tidal streams.

Speaking of Dr. Daniel's drift bottle experiments, Professor Johnstone tells us that the bottles employed by him (made at the Plymouth Marine Biological Laboratory and as used in the North Sea by the Ministry

of Agriculture and Fisheries) are, without doubt, superior to any similar instruments hitherto used. That they are superior to many earlier drift bottles may be admitted; that they are superior to all earlier used drift bottles cannot be agreed.

Dr. DANIEL's report on hydrographical investigations, deals with water samples drawn each midmonth of the years 1926—29 at four stations at 10 mile intervals from Holyhead Breakwater on the route to Ireland. Samples taken on the journey in one direction have been duplicated the next day on the return trip. Always, save for the last three months of 1929, the samples were dipped by canvas bucket; afterwards a Lumby surface sampler was employed. Double samples taken as quickly as possible with the canvas bucket, and therefore nearly at the same place, differed in salinity by 0.036 $^0/_{00}$ on the average. Lumby sampler dips yielded salinity figures differing on the average by 0.026 $^0/_{00}$ from those obtained by sampling with the canvas bucket. DANIEL finds that a discernible rhythm exists in the salinity of the Irish Sea due to Atlantic water inflow; his four years' data display a minimum salinity in August and September and a maximum about March, with, of course, variations in the actual salinity values as between year and year. These facts are held to reflect the flow of highly saline Atlantic water into the Irish Sea, "for it is known that the Gulf Stream Drift is usually strongest in the Spring and weakest in the Autumn".

One may agree with the author in referring the Irish Sea salinity extremes to the waxing and waning of the Atlantic Drift, but the remainder of his statement is open to question, if it be granted that the waxing and waning of the oceanic circulation can be inferred from the varying rate of flow of water from English Channel to North Sea. For the years with which Dr. DANIEL deals, the mean current through Dover Straits has been at a minimum in spring and at a maximum in autumn. Data exist to show that February ends a period during which the flow of water up-Channel has been at a maximum and August ends a period during which the opposite has been the case. The reviewer suggests that this is a reflection of "Atlantic activity" and sees in it an adequate explanation of Dr. DANIEL's findings as to times of salinity maximum and minimum. His extreme salinities would seem to be better explained as the result of happenings during several months beforehand. The author cites two notable deviations from the average annual rhythm, and it is interesting that he should refer to times at which the Dover Straits currents were abnormal.

The account of surface drift bottle experiments in the Irish Sea is by Dr. DANIEL and Miss LEWIS. Every month for a period of two years (July 1925—June 1927), bottles were thrown out from mail boats plying between Holyhead and Kingstown, at ten mile intervals from Holyhead Breakwater. Of 1180 bottles set free, 596 (= $50^1/_2$ $^0/_0$) were ultimately recovered, and of these, 84 had travelled north through the North Channel and up the west Scottish coast. No bottle passed out south through St. George's Channel. The authors present ample relevant wind data in the convenient form of period residuals. The bottle movements were found to be markedly dependent upon the winds, though not exactly parallel to their preponderant directions.

Most bottles stranded towards the north-east; a number went ashore south of the line of distribution on the Welsh coast, but none were recovered south of Wicklow Head on the Irish side. Those which stranded to the north-east had travelled to the left of the residual wind, whereas the majority of bottles which landed in the south east quadrant had travelled to the right. The author's main finding is that there exists a residual current in the Irish Sea running from south to north, but weak enough to be stopped or reversed by persistent northerly winds. The authors evaluate the factors when an equation of WITTING's type (Current speed $= k \times \sqrt{\text{wind speed}}$) is applied to their data. Bottle rate of travel in cms./sec. is found by the authors to be about $^1/_4$ the square root of the wind's speed in cms./sec. for the individuals which stranded in the NE. and NW. quadrants, and about half as much for bottles which landed in the SE. quadrant — facts accordant with the idea of a north-going residual current.

J. N. CARRUTHERS.

RUDOLF KÄNDLER. Untersuchungen über die Beziehungen zwischen Wasserstoffionen-Konzentration, freier Kohlensäure und Alkalinität im Meerwasser. Internationale Revue der gesamten Hydrobiologie und Hydrographie. Bd. 24, Heft 3—4, S. 177—224. Leipzig, 1930.

In his thorough experimental research the author sets himself the task of investigating the mutual relations of the quantities in question over a wider range than has hitherto been done by MCLENDON, BUCH and others in works dealing with the same subject, i. e. for the whole range of the alkali reserve in sea water down to 0.

First of all, the manner in which pH and the free CO_2 or CO_2-tension are affected by successive additions of sulphuric acid to sea water is made the subject of investigation. The addition of acid is equivalent to a diminution of the alkali reserve; it thus has the character of a titration, and the pH-alkali reserve curve is a titration curve with two neutralisation points, corresponding to the two dissociation steps of carbonic acid. The same relation with constant CO_2-tension, viz., that of atmospheric air, is investigated, and further the relation pH-CO_2-tension with varying alkali reserve. The results arrived at are given in tables and empiric diagrams. The relation pH-log (Alk.) is linear. Similarly straight lines are obtained for the relation pH-log (free CO_2) with unchanged alkali reserve. Variation of the latter is shown by a sideways displacement of the curves, with little deviation from the parallel. The relation Alk-log (free CO_2) (with constant pH) also gives straight lines. The lines drawn for various values of pH — from 4.7 to 8 — with equal pH intervals, radiate from the common zero point. (Alk. and $CO_2 = 0$). The relations obtained enable one to calculate one of the variables, provided the other two are known. The influence of salinity and temperature is discussed, but not investigated.

The author attempts to interpret the results theoretically, in the first place in connection with an earlier investigation by BUCH in 1917, making use of the dissociation equation of carbonic acid for the first dissociation step, and, in contrast to the opinion held by J. T. SAUNDERS, he arrives at the conclusion that sea water differs considerably from, *e.g.*, a simple Na-carbonate-bicarbonate solution.

He exhibits the results of his investigations in the following equation

$$pH = 0.936\ pK_1 + 0.89\ \log \frac{[Alk]}{[CO_2]}$$

in which pK_1 is the negative logarithm of the first dissociation constant of carbonic acid (valid only for infinite dilution) and $[CO_2]$ is the free carbonic acid in Mol/L, proportional to the CO_2-tension. Giving the constants a common value of 0.92 and introducing the Num. log the equation runs

$$H = \left(\frac{K_1\ [CO_2]}{[Alk]}\right)^{0.92},$$

an equation which presents the results arrived at by KÄNDLER in their most summary form.

The deviation from the state of a pure Na-carbonate-bicarbonate solution is indicated in the first place by the exponential value of 0.92 instead of 1.00. The author has allotted this figure the value of a constant. There is, however, hardly any doubt that the difference 1.00—0.92 is to be ascribed to the effect of the neutral salts, or that, with declining salinity, the exponential value approaches unity. It is not yet known in accordance with what law this occurs.

It is most interesting to compare KÄNDLER's results with those obtained by others. In a work by BUCH — Rapp. et Proc. Verb. Vol. LXVII, 1930 — an experimental series with water at 27 $^0/_{00}$ gives on recalculation in the same way as KÄNDLER has done, the exponential value, 0.90, agreeing well with the latter's results; this fact shows the reliability of these two investigations, which were carried out quite independently of each other. These results are further confirmed by the experimental experience gained by H. WATTENBERG, of the German "Meteor" expedition. According to verbal information received from WATTENBERG, his experimental results at 18° agree exactly with those arrived at by BUCH. The whole question of the mutual relations of the carbonic acid factors is thus nearing at least an empirical solution, to which the author has made a valuable contribution. Various details in the observations are still difficult to account for, especially if one tries to fit them to the theory — difficulties which in part have already been remarked by earlier workers, — but which, however, are to some extent attributable to the inadequacy of the theory itself. One of the most important questions in this respect is that of the influence of the neutral salts, which leads us to the general problem of electrolytic dissociation of the strong electrolytes, which is still far from a solution.

KURT BUCH.

S. KEMP, A. C. HARDY and N. A. MACKINTOSH. Discovery Investigations, Objects, Equipment and Methods; Station List 1925—1927. Discovery Reports. Vol. I, pp. 1—232.

Mit einer bemerkenswerten Pünktlichkeit und in einem sehr ansprechendem Gewande beginnen die wissenschaftlichen Ergebnisse der »Discovery«-

Expedition zu erscheinen, die in den Jahren 1925 —1927 im Südatlantischen Ozean am Rande der Antarktis biologisch und ozeanographisch tätig war. In den beiden ersten Bänden veröffentlicht das Discovery-Committee zwei wertvolle Beiträge zur Frage der biologischen und ozeanographischen Beobachtungstechnik, die einen lehrreichen Einblick geben in die wissenschaftlichen Arbeitsmethoden der Expedition.

Im ersten Teil gibt der Expeditionsleiter, Stanley Kemp, einen Überblick über die speziellen Forschungsaufgaben der Expedition. Im Mittelpunkt der Untersuchungen steht das Problem der Ökologie und Biologie der Wale, dessen Lösung im Hinblick auf die verheerenden Folgen des Walfanges in den anderen Fanggebieten der Erde auch vom ökonomischen Standpunkte aus als dringend geboten erscheint. Die Bearbeitung dieses Hauptproblems wurde von der Expedition auf mannigfaltige Weise in Angriff genommen: einerseits durch spezielle anatomische Untersuchungen der an den Walfangstationen in Grytviken (Südgeorgien) und in Saldanha-Bay (Kapland) eingebrachten Wale und andererseits durch hydrobiologische Untersuchungen in den von den Walen bevölkerten Meeresgebieten. Praktische Gründe zwangen die Expedition, zunächst von einer systematischen ozeanographischen und biologischen Erforschung des ganzen südlichen Meeresraumes durch enggelegte Tiefsee-Stationen abzusehen und sich auf folgende Arbeiten zu beschränken: 1) eine eingehende hydrobiologische Aufnahme der küstennahen Gewässer rund um Südgeorgien, 2) vereinzelte Querprofile mit ozeanischen Stationen hauptsächlich zwischen den Falkland-Inseln, Südgeorgien, Südshetlands-Inseln und Kap Horn und 3) Markierungsexperimente zur Feststellung der Walwanderungen. Da sich für die letzte Aufgabe die »Discovery« als zu langsam erwies, wurde im August 1926 der neuerbaute Forschungsdampfer »William Scoresby« in den Dienst der Expedition gestellt.

Waren somit letzten Endes praktische Ziele für die Problemstellung und das Arbeitsprogramm massgebend, so wurden doch, wie ein Blick in die recht übersichtliche »Station List« und in die beigefügten Stationskarten lehrt, in umfangreicher Weise wissenschaftliche Untersuchungen an den einzelnen Stationen durchgeführt. Die Liste verzeichnet 299 Beobachtungsstationen der »Discovery« in der Zeit vom 16.XI.1925 bis 4.IX.1927 und 136 Stationen des »William Scoresby« in der Zeit vom 25.VIII.1926 bis 17.VI.1927. Bei der Mehrzahl dieser Stationen handelt es sich zwar um Untersuchungen (besonders Netzfänge) in den obersten Schichten des Ozeans. Hydrographische Reihenmessungen bis zu 1000 m Tiefe und darüber wurden an insgesamt rund 50 Stationen durchgeführt. Von besonderer Bedeutung für das Problem der ozeanischen Zirkulation ist ein Querprofil durch die Drake-Strasse mit 5 Tiefsee-Stationen, ein bis 1000 m (bezw. 1500 m) Tiefe reichender Schnitt von Südgeorgien zu den Falklandsinseln (mit 4 Stationen) und ein Schnitt Tristan da Cunha-Südgeorgien (mit 6 Stationen). Auf dem grossen Profil Falklandsinseln-Kapstadt, das in einem grossen nach N bis 33° S geschwungenen Bogen die Westwindzone quert, konnten wegen ungünstiger Wetterverhältnisse nur 8 tiefreichende Stationen durchgeführt werden. Die auf diesen Profilen ausgeführten Tiefseestationen sind im allgemeinen zu weitabständig, um für sich allein die Grundlage einer dynamischen Bearbeitung zu bilden, und es ist daher

dankbar zu begrüssen, dass die physikalisch-chemischen Beobachtungswerte *in entenso* in der »Station List« der wissenschaftlichen Welt für die Bearbeitung der verschiedenen schwebenden Probleme zugänglich gemacht werden. Kleine Teilgebiete hat die »Discovery«-Expedition in mehr systematischer Weise ozeanographisch erforscht, so die nähere Umgebung von Südgeorgien in 7 radial von der Insel ausstrahlenden Schnitten, ferner das Bransfield-Becken durch 2 Querprofile und schliesslich die Gewässer westl. Kapstadt durch eine ganze Anzahl von Stationen.

Im zweiten Teile geben Stanley Kemp und A. C. Hardy eine eingehende Beschreibung der beiden Forschungsschiffe, ihrer wissenschaftlichen Ausrüstung und der auf ihnen angewandten Untersuchungsmethoden. Wir erhalten interessante nähere Mitteilungen über die Geschichte des Forschungsschiffes »Discovery« (65 m lang, 1300 t), das ursprünglich (1901—03) für die Polarforschung gebaut nach verschiedenartiger ruhmreicher Verwendung schliesslich vom »Discovery-Committee« erworben, gründlich repariert und umgebaut wurde. Als Vollschiff getakelt erwies sich die »Discovery« trotz ihrer polaren Qualitäten und trotz aller Umbauten schliesslich nicht besonders geeignet für ein ozeanographisches Forschungsschiff. So mussten z. B. wegen des Takelwerkes, insbesondere wegen des laufenden Guts, die ozeanographischen Beobachter aussenbords auf einer Plattform stehen, was bei Seegang auf dem stark rollenden Schiff die Untersuchungen sehr erschwerte. Auch befand sich die Hauptwinde für die biologische Arbeit hinter dem Hauptmast nicht in idealer Aufstellung. Für die ozeanographischen Arbeiten und die vertikalen Planktonfänge waren nicht weniger als 3 leichtere, mit Dampf betriebene Decksmaschinen auf Backbordseite aufgestellt, von denen 2 mit 6400 m Drahtlitze, die dritte mit 2 mal 900 m Litze (auf 2 Trommeln) bewickelt waren. In ausgiebiger Weise wurde bei der Führung der Instrumentenlitze von Gleitrollen, Zwischenrädern und Spannungsreglern (sogenannten Akkumulatoren) Gebrauch gemacht, wodurch einerseits sich der Betrieb der Maschinen etwas komplizierter gestaltete, andererseits aber die Zugbeanspruchungen der Haupttrommeln gemildert wurden. Von besonderem Interesse sind die Eigenschaften der in England hergestellten Drahtlitzen aus verzinktem Gusstahldraht, die auf der »Discovery« und auf der »William Scoresby« für die verschiedenen Zwecke Verwendung fanden. Zum Vergleich mit den auf anderen Expeditionen verwendeten Litzen seien hier die Werte (vom Referenten auf m und kg umgerechnet) wiedergegeben.

Eigenschaften der auf der »Discovery«-Expedition verwendeten Litzen und Trossen (aus verzinktem Gusstahldraht):

Zweckbestimmung	Oceanograph. Serienmessungen Vertikalfänge	Leichte Plankton-netze	Horizontalfänge	Grosse Planktonnetze	Trawl- u. Dredgezüge	
					Discovery	W. Scoresby
Durchmesser (mm) ...	4	6	9—13	12—14	13	2
Umfang (mm)	12	19	28.5—41.3	38.1—44.5	41.3	63.
Anzahl Drähte	6×7	6×7	6×7, 6×12, 6×19	6×12, 6×17, 6×19	6×17	6×1
Bruchlast (kg)	1010	2310	4570—10060	7420—11180	10060	2134
Gewicht pro 1000 m (kg)	55	128	460 (Mittel)	594 (Mittel)	610	156
Benutzte Längen (m).	910 / 6400	25×220 / 6400	6400	9140	1830	183

Die Zugbeanspruchung der Drähte wurde bei stillstehender Trommel durch ein Salter Dynamometer kontrolliert. Als Lotmaschine wurde die bekannte Lukaslotmaschine verwendet, die mit Pianodraht von 0,7 mm Durchmesser bewickelt war. Bei stärkerem Seegang gestalteten sich die Drahtlotungen auf dem stark rollenden Schiff sehr schwierig. Schon aus diesem Grunde hätte sich der Einbau einer modernen Echolotanlage sehr gelohnt, ganz abgesehen von den reichen wissenschaftlichen Resultaten, welche ein ständiges Ablesen eines Echolotes (für grosse Tiefen) bezüglich der Morphologie des Meeresbodens in diesen wenig erforschten Gebieten gebracht hätten. Zwei Laboratorien, von deren zweckmässiger Einrichtung man durch Wort, Bilder und Pläne einen Begriff erhält, vervollständigen die Ausrüstung der »Discovery«.

Der Forschungsdampfer »William Scoresby« entspricht dem Typus eines modernen Walfangdampfers, verfügt über starke Maschinen (1050 PS) und hohe Geschwindigkeit (12 Sm), und ist wesentlich stärker gebaut als die »Discovery«. Seine wissenschaftliche Ausrüstung musste aus Raumgründen kleiner gehalten werden; sie bestand aus einer grossen Winde mit 3 Trommeln für Otter Trawl-Züge und Planktonuntersuchungen und 2 kleineren Decksmaschinen für die übrigen biologischen und ozeanographischen Arbeiten. Das Schiff besass ferner eine Echolotanlage für kleine Tiefen (im Maximum bis 230 m Tiefe verwendbar), die sich bei der praktischen Durchführung der Trawl- und Dredgezüge sehr bewährt hat. Auf grösseren Tiefen wurde gelegentlich mit der Lukaslotmaschine gelotet.

Den Hauptteil des Berichtes über die angewandten Apparate und Methoden bildet die Beschreibung der Planktonnetze und der zahlreichen Hilfsapparate für diese biologischen Arbeiten. Der Ozeanograph gewinnt aus diesem Berichte den Eindruck, dass die biologischen Apparate und Methoden durch die »Discovery«-Expedition zu einem hohen Stande der Beobachtungstechnik entwickelt wurden, und dass biologische Tiefsee-Arbeiten vielfach weit grössere technische Schwierigkeiten bieten als physikalisch-ozeanographische. Es kamen nicht weniger als 6 verschiedene Netzgrössen für die vertikalen, schrägen und horizontalen Fänge zur Verwendung, das grösste von diesen besitzt die enorme Öffnung von $4^1/_2$ m und ist wohl das grösste Horizontalnetz überhaupt. Von besonderem Interesse sind die zahlreichen neuartigen Hilfsmechanismen, die für die Auslösung der Schliessvorrichtungen der Planktonnetze verwendet wurden, ferner die stromlinienförmigen Beschwerungsgewichte und die Hilfsapparate zur indirekten Ermittlung der Beobachtungs- bezw. Schlepptiefen bei den horizontalen Netzfängen. Letztere wurden übrigens vielfach ersetzt durch »schräge« Netzfänge, die sich als ertragsreicher herausstellten. Die ozeanographischen Instrumente und Methoden der »Discovery«-Expedition entsprachen dem neuesten Stande der damals in der »Internationalen Meeresforschung« erprobten Beobachtungstechnik. Inzwischen haben die Erfahrungen der Deutschen Atlantischen Expedition auf »Meteor« 1925—27 eine Reihe von Modifikationen gebracht, welche die ozeanographischen Reihenmessungen mit grösserer Zeitökonomie und vielfach auch mit grösserer Exaktheit durchzuführen gestatten. Es sei hier beispielsweise der Verzicht auf Abfallgewichte bei den Drahtlotungen, die reichere Verwendung von Serienwasserschöpfern (nach dem Prinzipe von Nansen) und

die Einführung feinerer Kippthermometer bei den Serienmessungen erwähnt. Für künftige Arbeiten in diesen stürmischen Zonen, in denen meist ein Drahtwinkel auftritt, sei der Wunsch ausgesprochen, dass regelmässig jeder Beobachtungsserie wenigstens 2 ungeschützte Kippthermometer zur thermometrischen Tiefenbestimmung mitgegeben werden, welche die wahre Beobachtungstiefe zu berechnen gestattet. Nach den Erfahrungen der »Meteor«-Expedition macht die Nichtberücksichtigung dieser Fehlerquelle die grosse Genauigkeit der Temperatur- und Salzgehaltsbestimmung (auf $^1/_{100}$) vielfach illusorisch.

Den Schluss des Bandes bildet eine eingehende Beschreibung der von dem »Discovery-Committee« in Grytviken (Südgeorgien) errichteten Biologischen Station aus der Feder von W. A. Mackintosh, die allen an ein modernes hydrobiologisches Laboratorium zu stellenden Anforderungen entsprach.

Alles in allem werden die beiden ersten Lieferungen der »Discovery«-Reports, die eine Fülle praktischer, vielfach unter schwierigen Verhältnissen gewonnenen Erfahrungen enthalten, von allen Ozeanographen dankbar begrüsst werden und in ihnen den Wunsch erwecken, dass diese bedeutungsvollen Forschungen fortgesetzt und weiter nach S auf die eigentliche Antarktis ausgedehnt werden. Hier kann durch systematische Reihenmessungen entscheidendes Beobachtungsmaterial für die Frage der Entstehung des antarktischen Bodenwassers gewonnen und damit bis zur primären Kraftquelle der stratosphärischen Zirkulation vorgedrungen werden; hier lassen auch ständige Echolotungen reiche neue Aufschlüsse über die Morphologie des Südpolarbeckens erwarten. In vorbildlicher Weise lehren die bisher von der »Discovery«-Expedition durchgeführten Arbeiten, dass es bei der Verfolgung des Walproblems möglich ist, praktische Ziele mit rein wissenschaftlichen Forschungen zu vereinigen.

Georg Wüst.

M. Nicloux. Le dosage de l'oxygène dissous dans l'eau de mer. Bull. de l'Inst. Océanog. No. 563. Monaco, 1930.

In order to estimate the dissolved oxygen in small samples of water — 5 to 40 c.c. — a special reaction vessel was used, in place of the usual glass stoppered bottle. This has the form of an inverted **Y** and contains a glass ball which can be rolled from one arm to the other to ensure complete mixing. It is filled with the water of which it is desired to determine the dissolved oxygen content: alkaline iodide solution is run into one arm and a solution of manganous sulphate or chloride into the other, by means of fine pipettes; a rubber stopper carrying a semicapillary tube is then inserted as far as a mark on the glass. The contents are mixed by rolling the glass ball backwards and forwards from one arm to the other, and the resulting manganese hydroxides dissolved by adding a small quantity of phosphoric acid through the tube in the stopper. The heavy acid runs down the fine bore tube, which was full of water. The stopper is then withdrawn and the contents poured into a beaker or flask for titration of the iodine set free. A microburette with N/100 or N/200 sodium thiosulphate solution was used, with starch solution as indicator.

The values obtained agreed to within 0.5 % when using 40 c.c. of water and to within 2 % when using 5 c.c. of water.

H. W. H.

A. Rundo. Sur l'évaluation de l'apport des eaux fluviales à la Baltique. IIIème Conférence hydrologique des États baltiques. Warszawa, 1930.

Der Verfasser hebt in seinem Vortrag die Bedeutung einer neuen Bestimmung des Süsswasserzuflusses in die Ostsee hervor. Bisher ist diese Frage allgemeiner von Krümmel, Keller, Spethmann und besonders vollständig von Witting behandelt worden. Die verschiedenen Berechnungen und Schätzungen beziehen sich auf ein etwas heterogenes Material, so dass die Ergebnisse, wie der Verfasser an einigen Beispielen zeigt, nicht ganz zuverlässig sind und oft den Charakter einer ersten Approximation tragen. Es werden einige Vorschläge für weitere einheitliche Berechnungen gemacht, wodurch genauere Werte des Zuflusses in die einzelnen Meeresgebiete hervorgehen würden. Solche Berechnungen wären auch für die genauere Bestimmung des Wasseraustausches zwischen Nord- und Ostsee von grösster Bedeutung. E. Palmén.

Bruno Schulz. Der Wasseraustausch zwischen Nord- und Ostsee. Petermanns Mitteilungen. Ergänzungsheft Nr. 209. Gotha 1930.

Der Verfasser behandelt in der vorliegenden Arbeit den Wasseraustausch zwischen Nord- und Ostsee, wobei sowohl der durchschnittliche, jährliche Austausch wie auch seine Schwankungen besprochen werden. Mehrere Forscher haben wie bekannt schon früher diese Fragen eingehend untersucht, und in allernächster Zukunft wird dieses Problem bekanntlich Gegenstand einer international organisierten Untersuchung. Der Verfasser gibt in seiner Arbeit eine kurze Übersicht der bis jetzt bekannten Tatsachen und versucht, Zahlenwerte des Wasseraustausches zu geben. Von grösstem Einfluss auf den Wasseraustausch zwischen Nord- und Ostsee hat sich die morphologische Grenze der Ostsee erwiesen, weil die hier befindlichen flachen Schwellen, die Darsser Schwelle (Tiefe: 18 m) und der Sund (Tiefe: 7 m), die Einströmung von atlantischem Wasser sehr erschweren.

Unter Beachtung der von R. Witting mitgeteilten Werte für die Ostsee betreffs Süsswasserzufluss, Niederschlag und Verdunstung lassen sich unter Beachtung der Knudsen'schen Relation die im Unter- und Oberstrom transportierten Wassermengen berechnen. Der Verfasser verwendet für Süsswasserzufluss + Niederschlag − Verdunstung den jährlichen Wert 500 cbkm und erhält folgende Zahlenwerte:

	Skagen-Paternosterschären	Fornäs-Skalle Riff	Schwellen an der Westgrenze des Arkonabeckens
Oberstrom	2750 cbkm	1400 cbkm	1000 cbkm
Unterstrom	2250 —	900 —	500 —
Dem Unterstrom beigemischte Menge von Wasser mit 33‰	2250 —	750 —	167 —

Nach diesen Werten werden nur etwa 7 % des im Unterstrom in das Kattegatt geführten Wassers von 33 ‰ bis in die Ostsee transportiert, während die übrigen 93 % sich mit dem Ostseewasser zu dem in das Skagerrak fliessenden Wasser des baltischen Stromes vermischen. Weiter wird etwa ein Drittel des im Oberstrom westlich des Arkonabeckens die Ostsee verlassenden Wassers wieder durch den Unterstrom in die Ostsee zurückgeführt. Diese Werte zeigen, welche hervorragende Bedeutung die Mischungsvorgänge in diesen Gebieten haben. Dies geht u. a. auch daraus hervor, dass nach den Beobachtungen von Jacobsen der ausgehende Strom im grossen Belt auf geringeren Tiefen, wo kein Unterstrom vorhanden ist, gewöhnlich grössere Geschwindigkeit besitzt, als auf grösseren Tiefen, wo der Unterstrom voll ausgebildet ist.

Weiter berechnet der Verfasser unter Benutzung der Witting'schen Mittelwerte den Wasseraustausch zwischen Nordsee und verschiedenen Teilen der Ostsee und findet u. a. folgendes: »Von dem insgesamt bis in die Ostsee geführten atlantischen Wasser gelangen zwei Fünftel in den Finnischen und Bottnischen Meerbusen und ein Zehntel bis in die Bottenwiek«. Die Mischung in der Ostsee zwischen Ober- und Unterstrom ist somit viel kleiner als im Grenzgebiet zwischen Ost- und Nordsee.

Bei Untersuchung des Wasseraustausches in einzelnen Monaten oder in ganz speziellen Fällen ergibt sich ein ganz anderes Bild. Der Verfasser bemerkt, dass die Untersuchungen von Witting und Jacobsen einen ausgeprägten jährlichen Gang in den Abflussmengen ergeben haben (Maximum im Frühling). Weiter wird die Frage der internen Wellen und ihre Bedeutung für den Wasseraustausch berührt; die Wirkungen solcher internen Wellen, deren Bedeutung besonders O. Pettersson hervorgehoben hat, sind jedoch noch nicht genügend nachgeprüft. Auch neue Untersuchungen über säkulare Schwankungen der Schonenfischerei geben keine Anhaltspunkte für die Annahme säkularer, kosmischer Schwankungen in dem Wasseraustausch. Dagegen wird an einigen Beispielen gezeigt, welch grosse Bedeutung für die Fischerei das wahrscheinlich meteorologisch bedingte »kaskadenartige« Vordringen von Wasser aus dem Kattegatt in die Beltsee und weiter in die Ostsee hat. Eine Zusammenstellung von Extremwerten des Salzgehaltes bei den Feuerschiffen Drogden und Gjedser-Riff gibt eine gute Vorstellung von dieser Erscheinung. E. Palmén.

H. Thorade. Ebbe und Flut in der Nordsee. Ein geschichtlicher Rückblick. Petermann's Mitteilungen. Ergänzungsheft Nr. 209. Gotha, 1930.

This article represents a piece of scholarship of a type which one could wish were more frequent. In approximately chronological order it follows all the attempts that have been made during the last hundred years to elucidate a well-defined subject of mathematical, physical, geographical, navigational and general interest, assigning these attempts to natural scientific epochs and indicating their significance from wider points of view. Dr. Thorade has a complete mastery of his subject, so that one of his sentences often summarises the results of a close study of a number of

memoirs. As he points out, the tides of the North Sea have always served as a kind of touchstone by which to test hypotheses and methods of investigation, and in consequence, their study is associated with a long line of illustrious men, beginning with YOUNG, WHEWELL, AIRY and KELVIN and including the lately deceased STERNECK and MERZ. Dr. THORADE has heightened the human interest of his subject by apt references to the distinctive qualities in the genius of these men.

Tidal charts for the North Sea have appeared since 1833 but for ninety years they showed the most astonishing mutual contradictions. Then, almost simultaneously, three charts appeared, one in Germany, one in Austria and one in England, produced in entirely different ways and yet agreeing in their major features. In discussing the minor differences exhibited by these charts Dr. THORADE is scrupulously fair and he endeavours to soften, as far as the North Sea is concerned, the somewhat hard criticisms often aimed at the intrepid DEFANT by the thorough STERNECK.

The article ends with the enunciation of two outstanding questions and a hope that, as an avenue of research, the North Sea will lead to the oceans. The first of these outstanding questions concerns the effect of local variations of the depth of the sea on the curvature of the cotidal lines. In defence of the smoothly running lines of the chart prepared by DOODSON I should like to state my opinion that until one is sure which way a line curves it is better to draw it straight. The second outstanding question concerns the vagaries, over the North Sea and especially in the Skager Rack, of the maximum effects which follow new and full moon. In this connection I venture to suggests the following tentative explanation.

In the absence of friction the cotidal lines for the principal solar constituent would be similar to those for the principal lunar constituent except that, as the solar period is shorter, the solar amphidromic point to the north of Holland would lie to the south of the lunar one. The effect of friction on the solar constituent will be relatively smaller than on the lunar constituent owing to the smaller currents and therefore the solar amphidromic point will lie nearer the medial line of the sea than the lunar one, while there may be another solar amphidromic point off the south of Norway. It is this modification of the amphidromic points which may cause a relative diminution in phase-lag for the solar constituent on the eastern coasts of the sea. J. PROUDMAN.

C. M. YONGE. A Year on the Great Barrier Reef. The story of Corals and the greatest of their Creations. (Putnam. London & New York). 1930.

Among the various books written on that great subject, the Coral Reefs — the classical book by DARWIN, SAVILLE KENT's splendid work on the Great Barrier Reef of Australia, WOOD-JONES' fine book on the Cocos Islands etc. — the present book easily maintains its rank in the first line, combining, as it does, a very clear representation of the scientific facts and theories relating to the coral reef problem in general with a vivid description of the investigations carried out by the Great Barrier Reef

Expedition, and a charming relation of the daily life on the little Coral Island, where the party of which the author was a member spent nine months, from July 1928 to March 1929.

It will, of course, take a long time before the reports on the various investigations carried out by the expedition will have been published and the final results summed up. But it appears already that, on the whole, the investigations tend to show all the various theories set forth to explain the origin of the coral reefs — the DARWIN-DANA theory, MURRAY'S and STANLEY GARDINER'S theories, DALY'S Glacial-control theory — to contain some truth. Although the Darwinian theory evidently maintains the supremacy, neither this nor any of the other theories can claim to be the sole explanation of the whole coral reef problem. Every group of coral reefs contains its own problems and is to be studied by itself. It is a matter of great satisfaction that the greatest coral reef formation of the world has now been made the object of study on a large scale, after a carefully worked out plan, which will result — it seems clear already — in a full understanding of the origin of this wonderful reef and of Australia's "Grand Canal".

A striking feature of the book is the profusion of excellent illustrations, which will greatly help every one, who has not himself had the good fortune of seeing a coral reef in nature, to realise the marvellous beauty and grandeur of this wonder of nature. The photo of the expanded *Turbinaria*-polyps (Pl. XV) may be pointed out, the reviewer remembering well the impression made upon him by a nearly pure *Turbinaria*-reef at Banda, with the millions of flower-like polyps expanded!

Among the numerous important observations may be pointed out that of the destruction caused to coral reefs by hurricanes; it is shown beyond doubt that one of the main reasons for the killing of corals and other reef organisms is the torrential rain accompanying the cyclones, making the surface layers of the sea almost fresh. The influence of trade winds on the shape of the coral reefs is duly acknowledged. The important question of the part played in the physiology of corals by the parasitic algæ (*Zooxanthella*) living in them has, of course, been made the object of much investigation. The result arrived at, that they are not at all used by the corals as food, is at variance with the results recently achieved by BOSCHMA. This problem, therefore, invites further investigation.

A rather surprising fact is this that the investigations by G. H. DREW on the precipitation of Calcium Carbonate in the sea by marine bacteria (*Bacterium calcis*) are not mentioned at all. Does that really mean that this important factor in the formation of the fine calcareous mud in coral lagoons has been overlooked? In this connection a rather disfiguring feature of the book may be pointed out, viz. the several erroneous spellings of names: *Catappa* (for *Calappa*), *Tricodesmium* (for *Trichodesmium*), *Margaratifera* (for *Margaritifera*), *Retipora* (for *Retepora*), *Fierasper* (for *Firasfer*), *Salmacus* (for *Salmacis*; the latter being described as a sand-burrowing sea-urchin of elongate form, evidently a Spatangoid is meant, not at all a *Salmacis*, which is a regular, not sand-burrowing Echinoid). On the other hand the correct spelling of the name "Snapper" is a pleasure to the reviewer, who has so often been disgusted in seeing this name written

in the German form "Schnapper" both in Australia, New Zealand and South Africa on the menus of the restaurants, even on the menu of English passenger ships!

The numerous organisms associated with the corals and playing a great part in the ecology of coral reefs receive due attention, of course, and interesting observations are given on the giant clam, *Tridacna*, a real death trap to the fisherman, who unawares steps on it, the much dreaded "stonefish", *Synanceia*, which looks so exactly like an old, worn, dirty piece of coral block that it is almost indistinguishable, but when stepped upon stings with its fin rays, which are connected with poison glands, and thus causes at least horrible pain, sometimes even death; there is the walking fish, *Periophthalmus*, which is drowned when kept in water and prevented from coming up to breathe air, there are the "animated sausages", the Holothurians, the various boring organisms etc. But again the reviewer is surprised in not finding mentioned the Sea-lilies (Comatulids), those exquisite beauties generally so common on coral reefs and under coral slabs, so gloriously represented in H. L. Clark's report on the Torres Strait Echinoderms. Perhaps they are not so common at the Low Islands, where the expedition stayed, but then they might well have been mentioned under the description of the visit to Mer Island, the place where H. L. Clark made his investigations. Very amusing is the explanation given of the origin of the word "porcelain", from the white Cowrie shell, *Ovulum ovulum*, which was formerly known among collectors as the "little pig" (porcellinus).

Strongly opposed to the old belief, still recently set forth, that tropical animals are constantly breeding, are the numerous observations on the breeding of a number of coral reef organisms. They were all found to have a very pronounced periodicity, the breeding generally coinciding with the periods of full moon. Such periodicity has also been observed by Munro Fox and by the reviewer, and appears to be the rule for the littoral organisms of tropical seas.

It is a real "romance of the coral reefs" we have got in this delightful book. The life on a coral island is depicted so vividly that the reader would like to come and see it all for himself. The author, however, justly remarks, "let no one think that life on a coral island is unending bliss. For a short visit, if you choose aright the season and place, it can be perfection. But few Anglo-Saxons (and Scandinavians alike!) are so constituted that they can find paradise idly lying surrounded by palm trees in the sun on the coral sand of a tropic Island". True! But all the same, the coral islands are among those spots which come the nearest to our ideas of a paradise, at least for those of us who are marine biologists, offering no end of opportunities for observation and investigation on problems of the greatest scientific interest, as well as of, once in a while, a *dolce far niente* under the shade of the palms all the while looking out over the sky-blue ocean.

Might one of the results of the Great Barrier Reef Expedition be the establishment of a permanent biological laboratory on one of the coral islands, giving access there for biologists, who cannot afford a great, costly expedition, to see a coral reef and work there under modern laboratory facilities!

Th. Mortensen.

HENRY B. BIGELOW and MAURINE LESLIE. Reconnaissance of the Waters and Plankton of Monterey Bay, July, 1928. Bulletin of the Museum of Comparative Zoology, Harvard. Vol. LXX, No. 5. Cambridge, Mass., 1930.

This paper describes in detail a survey made in July 1928 of the waters of Monterey Bay, a shallow bight 20 miles long and 11 miles deep on the coast of California. The region is interesting in that the edge of the continental shelf comes very close to land and that chemical and hydrographical conditions are largely determined by the upwelling of cold saline water rich in nutrient salts. Although the survey lasted only a month, figures for temperature and salinity were available for the surface water near the shore for several years. By a careful comparison of these with figures from other places on the Californian coast, the authors are able to conclude that the conditions are much the same as elsewhere on that coast, and that there is periodic upwelling throughout the year. A trough about 1000 metres in depth runs up into the bay and it is in this region that the upwelling is most obvious. The deep water is pushed up the sides of the trough and overflows on to the shallower slopes of the bay. Waters rich in nutrient salts are found in this position but spread further over the slopes than water of correspondingly low temperature and high salinity; the authors therefore suggest that the addition of nutrient salts to the surface waters comes not only from deep water but also from the bottom on the shallower slopes, as it does in areas where the continental shelf is wide. In general Monterey Bay should be an area suitable for rich plant growth during the whole year.

The average diatom content of the water in the first half of July was high as compared with open Atlantic water and was higher than July samples from stations further south in California. A high diatom count usually, but not always, corresponded with a high oxygen content and a low phosphate content, but the distribution of diatoms and nutrient salts was irregular over the bay. In other words, the presence of nutrient salts in well illuminated regions is not the only cause governing the presence of the phytoplankton. Only continuous observations are likely to clear up this interesting point. There were indications that diatoms had been more abundant in the preceding month and were still decreasing in numbers.

The zooplankton was investigated qualitatively and showed a general resemblance to the neighbouring regions of the Pacific coast and even to similar situations in the North Atlantic. In July the plankton in the surface waters was mainly endemic and the abundance of young stages of copepods and euphausids indicated that these would play an important part later in the year. In the deep water of the trough a typical bathy-pelagic fauna was found.

Although restricted in scope, this survey is a useful introduction to the study of the effect of chemical and physical conditions on the distribution and amount of the plankton in an area of continuous upwelling, and shows how even a short survey can be of value when the conditions in neighbouring areas are understood. S. M. M. and A. P. O.

P. L. Kramp. Hydromedusae collected in the south-western part of the North Sea and in the eastern part of the Channel in 1903—1914. Mém. du Musée Royal d'Hist. Nat. de Belgique, no. 45. Bruxelles, 1930.

Dr. P. L. Kramp of the Zoological Museum of Copenhagen, one of the very few zoologists who has an intimate knowledge of the structure and behaviour of Hydromedusae, has lately given us a deal of very useful information on the life cycles of these animals. His paper on the regional distribution, seasonal occurrence and biological features of the hydromedusae found in those parts of the North Sea and British Channel forming the Belgian sphere of International plankton research shows clearly to what extent useful information can be extracted by an expert from the hydromedusan component of the plankton.

Dr. Kramp deals chiefly with the effects upon hydromedusan distribution of variations in the influx of Channel water into the southern part of the North Sea. The sort of result obtainable from such material and data as were collected from 1903—1914 may be indicated by the statement that in September 1908 medusae were brought into the coastal region off Belgium and France East of Calais by an unusual movement of Channel water towards the coast, and that in November this Channel water was retreating again. That the volume of water that flows through the Straits of Dover into the North Sea is not great is — according to Dr. Kramp — shown by the fact that even when the 35 $^{0}/_{00}$ isohaline has a particularly extensive distribution in the North Sea the characteristic hydromedusae of the Channel water are impressively scarce in the southern part of the North Sea. It is shown that many more samples of the plankton should have been taken, particularly in 1907, when, for instance, there was an exceptionally large influx of Channel water in November, and no medusae were taken. An interesting fact that comes out of the work is that the indigenous North Sea medusae are most abundant when there is least Channel water within that area. The author does not appear to be acquainted with the recent English work on the influx of Channel water into the North Sea, a perusal of which might lead him to modify some of his conclusions.

A. K. T.

A. C. Stephen. Studies on the Scottish Marine Fauna: The Fauna of the Sandy and Muddy Areas of the Tidal Zone. Trans. of the Royal Society of Edinburgh. Vol. LVI, Part II, No. 14. Edinburgh 1929.

A. C. Stephen. Studies on the Scottish Marine Fauna: Additional Observations on the Fauna of the Sandy and Muddy Areas of the Tidal Zone. Trans. of the Royal Society of Edinburgh. Vol. LVI, Part II, No. 22. Edinburgh 1930.

In these two papers the author has continued his quantitative examination of the fauna of the intertidal sands which was begun in 1926 in the Cumbrae, Firth of Clyde (Journ. Mar. Biol. Ass. Vol. XV, No. 2, 1928). Various other parts of the Scottish coast have now been investigated by digging out squares of 0.25 square metres of the sand and collecting the living animals contained therein. Only the molluscs and polychætes are

here dealt with. The first named paper describes the fauna on places in the Ayrshire coast, the Firth of Clyde, the south coast of Moray Firth, the Aberdeenshire coast, St. Andrews Bay, and the Firth of Forth; in the last named paper examples are given of the fauna of (a) a river mud-flat, (b) some grounds at the heads of sea lochs on the West Coast, and (c) the more exposed shores of the Western Islands.

Great variations were found in the density of population; the open shores usually were the poorest of all, in the most exposed places neither molluscs nor polychætes were found. The richest area found was in the Firth of Clyde. The shores examined fall into two types: (a) sandy shores, where *Tellina tenuis* predominates, and (b) shores which are part sand, part mud, where *Tellina tenuis* is dominant in the sand, and *Cardium edule* and *Macoma baltica* are dominant in the muddy part. Each species has its own area of distribution and region of maximum density; these areas follow each other in definite zones. Thus *Nereis diversicolor* was ordinarily found only at H. W. M.; *Macoma baltica*, *Cardium edule* and *Arenicola marina* were found to dominate in the upper half of the beach, *Nephthys coeca* and *Tellina tenuis* in the lower half. Other forms, like *Tellina fabula*, *Venus gallina*, *Donax vittatus* and *Travisia forbesii* were found almost exclusively at L. W. M. It is an interesting feature that all of these animal communities are met with in the Danish waters also, as described by C. G. Joh. Petersen in 1913.

The author concludes by stating that, besides the nature of the substratum, the nature of the feeding mechanism and the food of the dominant shore forms must be taken into consideration as governing factors for the above named peculiarities of distribution. The elucidation of these points is promised to be the aim of future work. H. Blegvad.

G. A. Steven. Bottom Fauna and the Food of Fishes. Journ. Marine Biol. Assoc. N. S. Vol. XVI, No. 3, pp. 677—706. Plymouth 1930.

Mr. Steven's paper contains a study of the bottom fauna of an inshore fishing ground near Plymouth, the "corner", together with observations of the stomach contents of fishes from the same place. At 15 stations quantitative seasonal investigations with the 0.1 square metre bottom sampler (the "Petersen Grab") have been made, and at 4 of these stations an "Agassiz" trawl with a 7 foot beam was used as a quantitative instrument, towing it over a definite distance each time; these hauls were repeated in the winter, spring, and summer seasons.

The bottom sampler hauls show a rather poor fauna, consisting mostly of different kinds of polychæta. Of the Crustacea two *Ampelisca* species were the most numerous, but in the winter season they were almost completely wanting in the hauls; the author suggests that *Ampelisca* may burrow deeply into the bottom during the winter months, beyond the reach of the bottom sampler. Both in the grab and the trawl records the infauna was found to be more richly represented than the epifauna. It is calculated from the grab hauls that the two species of *Upogebia*, *U. deltaura* and *U. stellata*, which were fairly uniformly distributed over the

whole area (13 sq. miles), made up a population exceeding 72 millions, 45 millions, 108 millions and 130 millions in the autumn, winter, spring and summer seasons respectively. The figures are all minimum figures, as the bottom sampler is not likely to capture more than a fraction of these agile, burrowing forms. It was in order to get an idea of the quantity of such agile crustaceans: *Portunus depurator*, *Pandalina brevirostris* and *Palæmonidæ*, important food animals of the "corner" area, that the author made use of the Agassiz trawl; it is rightly pointed out on p. 679 that the bottom sampler is not designed to capture these animals.

Every quantitative instrument has its definite limits, beyond which it cannot work satisfactorily; a small and light bottom sampler (0.1 sq. m.) is usually unable to dig up the deepest living animals from a hard and sandy bottom, whereas it works very well in a soft or muddy bottom. But a trawl also has its narrow limits for use in quantitative work, determined by 1) its ability to go more or less deep into the ground, 2) the rate at which it is towed, and 3) the size of the meshes. It must be this last named factor which is responsible for the fact that the author's Agassiz trawl, used over a total area of about 48500 sq. metres, brought up only 21 *Portunus pusillus*, whereas the bottom sampler, working over an area of 30 sq. metres, picked up 15 individuals of this species; thus the trawl has left behind more than 1000 *P. pusillus* for every single specimen taken up. For *Galathea intermedia* the figures were 48 and 13 individuals, respectively; so the bottom sampler took 438 times more individuals of this species per unit area than the trawl; but of the larger form, *Galathea nexa*, the bottom sampler brought up only 16 times as many individuals per unit area as the trawl.

Nevertheless, the trawl may very well be used, as the author has done, for seasonal comparative purposes. Thus the records show very clearly that although on the whole both number and distribution of most of the organisms remained fairly constant through the year, yet *Pandalina brevirostris* and some crangonids showed definite migratory movements shorewards in the spring.

As to the investigations of stomach content of fishes, the author confines himself to stating the number of stomachs containing different organisms, for different sizes of each fish species; no attempt has been made to count or weigh the food animals contained in the stomachs. Winter and summer observations are kept separately. A total of about 1900 fishes have been examined from the "corner" area, mostly consisting of Gadidæ, flat-fishes and gurnards. For *Gadus minutus* and *Gadus merlangus* over 10 cm. in length and for certain sizes of *Raia clavata* the *Megalopa* larvæ of *Corystes cassivelaunus* seem to be a very important food in May and June.

At the end of the paper some highly interesting observations on the feeding habits of fishes, as observed in aquaria, are given. The Lemon dab (*Pleuronectes microcephalus*) with its highly movable eyes hunts by sight: with the head and front part of the body raised well off the ground it remains perfectly still untill an unlucky worm emerges a little from its burrow; — then the Lemon dab suddenly pounces upon it with a kind

of forward leap, bringing its mouth down almost vertically upon its victim by a strong arching of the anterior part of the body. Also hermit crabs are seized when they venture to appear at the mouth of their shells. — Dab and plaice, too, are said to be visual feeders, but the sole (*Solea vulgaris*) in foraging for prey depends almost entirely on the tactile sense. The different species of gurnards seem more or less to use their long, finger-like pectoral filaments as tactile organs. *Trigla lineata* is mostly a "tactile feeder", *T. hirundo* mostly a "visual feeder". The rough dogfish (*Scylliorhinus canicula*) hunts by scent. H. Blegvad.

K. Altnöder. Bericht über die Untersuchungsfahrten zur Feststellung des Vorkommens von Herbstheringslarven in den Laichperioden 1928 und 1929. Ber. d. deutsch. wiss. Komm. f. Meeresforschung. N. F., Bd. V., H. 3. Berlin 1930.

Since 1927 a close co-operation has taken place between Denmark, Germany and Sweden in order to locate the spawning places of the autumn spawning herrings in the Kattegat, Belt Sea and the western and southern part of the Baltic. The spawning places have been located by means of fishing experiments with a two metres stramin ring trawl catching the newly hatched herring larvae. A short account of these investigations is published in the yearly reports of the Transition Area Committee (Rapp. et Proc.-Verb. du Cons. Perm. Internat., Vol. LXXI) by Dr. A. C. Johansen.

In the paper under review Dr. K. Altnöder has dealt in particular with the German fishing experiments with the ring trawl in the autumns of 1928 and 1929. In 1928 large numbers of larvae were found in the Great Belt as well as in the Kiel Bay, whilst in 1929 the numbers caught in these areas were rather small. The author is of the opinion that the coincidence in the numbers of larvae in these two neighbouring areas is due either to a congruity in the spawning intensity or to a comprehensive transport of larvae with the currents from the spawning places in the Great Belt to the Kiel Bay. In this connection he sets forth the view that the study of the transportation of larvae may have some importance for the racial investigations, as the transport may cause an intermingling of different races in the larval stage.

The author further deals with the fluctuations in the amount of larvae in different areas in the years 1927, 1928 and 1929. Here he very correctly pays the greatest attention to the distribution of the smaller larvae (5—9 mm.), as it is these newly hatched larvae which give us the best information as to the situation of the spawning places. It is stated that about 80 % of the larvae caught are between 5—9 mm., and ca. 20 % of the total number are furnished with a yolk-sac. In the opinion of the present reviewer a statement of the exact number of larvae with yolk-sac is rather difficult as the yolk-sac may be torn and therefore hardly be discernible. The numbers of larvae with yolk-sac given by Dr. Altnöder must thus be regarded as minimal. The fact that most of the larvae caught are below 10 mm. and not less than one fifth are found with yolk-sacs shows that the fishing has been carried out in the actual spawning season and on, or in the neighbourhood of, the spawning places.

It is further shown that the amount of larvae varies considerably from one region to another and that in general the largest amount of larvae is found in the middle part of the area investigated. It is the opinion of the reviewer that in subdividing the area of investigation into smaller regions more attention might have been paid to the natural conditions of the waters, especially the depth and the salinity.

The paper under review furnishes us with very valuable information concerning the distribution of the larvae of the autumn herrings in the waters investigated. It is to be hoped that these interesting investigations will be continued in future so that, on the basis of investigations from a series of years, we may be able to compare the yearly fluctuations in the amount of larvae, i. e. in the intensity of spawning, with variations in the hydrographical conditions.

The paper is accompanied by 5 very instructive figures giving a good survey of the results of the investigations. ERIK M. POULSEN.

H. HELDT. Le thon rouge et sa pêche (*Thunnus thynnus* L.) Nouveaux aspects de la question. — Station océanographique de Salammbô. — Bulletin no. 18. Paris, 1930.

Le Professeur HELDT continue avec le plus grand succès les recherches successivement apparues sur le thon; son travail n'est pas un simple résumé car il connait le problème à fond et ses connaissances lui permettent de donner son opinion et de discuter sur ce point. Il ne limite pas non plus son étude à la biologie de cette espèce; il commence son travail par la synonymie et en vient à poser les problèmes industriels qui sont d'un si grand intérêt dans certains secteurs de la côte Méditerranéenne ainsi que dans les eaux atlantiques non loin du détroit de Gibraltar.

La morphologie du thon et des espèces similaires ne donne pas de caractères suffisants pour classifier les formes, et les grandes dimensions des exemplaires empêchent de les collectionner ce qui complique étrangement la question synonymique.

FRADE a initié avec succès une étude statistique et méthodique en faisant des mesures comparatives.

On doit aussi a FRADE l'investigation anatomique du thon européen en le comparant avec une espèce très semblable morphologiquement, au *Thunnus orientalis* décrit en détail par KISHINOUYE.

D'après SELLA, la répartition géographique du thon est très étendue; la Méditerranée et une ample région de l'Atlantique sont peuplées par les mêmes individus. Les travaux de ROULE et F. DE BUEN n'admettent pas ce point de vue. C'est avec raison que HELDT après avoir exposé l'opinion de SELLA, fait observer combien peu précise est l'existence du *Thunnus thynnus* dans les zones proches au tropique, aux Açores et en Islande.

Il montre, en fin, les invasions périodiques de cette espèce dans la Mer du Nord et dans l'Atlantique comme cela avait été déjà signalé par LE GALL.

Quelques auteurs anciens croyaient fermement à l'existence d'une émigration verticale, ample et périodique de la part du thon, la masse des individus génétiques apparaissant brusquement à la surface des eaux.

BOUNHIOL, ROULE et F. DE BUEN s'opposent à cette théorie. D'après

les données accumulées par HELDT, il est possible que les individus s'approchent du fond, tandis que SELLA croit à la possibilité d'importants déplacements verticaux.

HELDT passe en revue dans un chapitre spécial les différentes proies dont s'alimente le thon et montre leur grande variété.

SELLA à fait une étude approfondie des hameçons recueillis dans le corps de ces grandes poissons et, se basant sur leur forme et leur manière d'être attachés, il en déduit leur origine et conclut à la possibilité de deux déplacements. Quant à nous, nous doutons de ces résultats car la méthode adoptée se prête à la critique.

Les conclusions générales de SELLA, en se basant sur la trouvaille des hameçons peuvent se résumer ainsi:

1) Rassemblement des thons en Mai—Juin dans la zone restreinte de réproduction, limité à la Méditerranée occidentale, le Golfe de Cadix jusqu'au cap Saint-Vincent et la côte N.W. du Maroc.
2) Mouvements successifs centrifuges, ou mieux dirigés essentiellement vers le nord, avec dispersion des thons dans toute l'étendue de leur vaste zone d'habitat.
3) Nouvelle réduction de l'habitat à l'approche de l'hiver.
4) Dans la période Mars—Avril précédant immédiatement le temps de la réproduction, le thon accomplit une nouvelle émigration vers le nord, comme l'émigration estivale, mais d'amplitude beaucoup plus limitée.
5) Après quoi, en Mai—Juin, nouvelle disparition de la zone nord pour la concentration génétique, puis le cycle recommence.

SELLA attribue la cause de la repartition du thon à l'influence du Gulf-Stream; HELDT est partisan des transgressions. Le même auteur italien suppose une différence de sensibilité à la température dans les individus de dimensions distinctes, opinion critiquée par HELDT.

L'auteur du travail que nous commentons passe en revue les opinions soutenues sur halotropisme et phototropisme, et en étudiant les races, il parle des récents découvertes de SELLA dont les détails restent à être publiés.

Enfin, il consacre un chapitre aux connaissances actuelles sur la ponte qui, à ce qu'il paraît, n'a pas lieu dans les madragues ou l'on prend le thon et à la croissance calculée en observant des zones hivernales sur les vertèbres.

Au sujet de la pêche, le Prof. HELDT étudie minutieusement les statistiques et leur fluctuations, d'un rythme séculaire d'après certains auteurs, et selon d'autres, aux changements non répétés pendant un long espace de temps.

Quelques conclusions opportunes terminent cet intéressant travail, difficile à résumer parce que les pages en sont destinées précisément à condenser les connaissances actuelles sur la vie et l'utilité du thon.

F. DE BUEN.

August Krogh. Über die Bedeutung von gelösten organischen Substanzen bei der Ernährung von Wassertieren. Zeitschrift für vergleich. Physiologie. Bd. 12, H. 3/4, S. 668—681. Berlin, 1930.

Whether dissolved organic substances in natural waters can or can not be used as a source of food by aquatic animals, has been a much debated question during the past two decades. Several attempts to prove or disprove the theory have been made, but the present investigation by Krogh is by far the most careful study of the problem that has yet been made. He has employed much more accurate apparatus and methods than his predecessors, and his results are, therefore, correspondingly much more reliable. Great care was exercised in reducing bacterial contamination to a minimum and his results were checked by two methods.

The experiments fall into two groups, namely (a) those in which grape sugar was employed and (b) those in which the dissolved organic substances found in natural waters were used. The latter experiments were performed for the purpose of avoiding the criticism that such substances as grape sugar are not present in natural waters, and therefore have no bearing on the problem. (In this connection it may be remarked that Wisconsin lake waters do not contain any sugars and only a very small percentage of the carbohydrate material that is present can be readily hydrolised into sugar.) In the grape sugar experiments, it was found that Daphnias, fish and tadpoles actually took up small amounts of the sugar in solutions of 5, 20 and 40 milligrams per litre, but the amounts absorbed were equivalent to only about a quarter of the gas exchange. At the same time organic substances in corresponding or larger amounts were given off to the water by the organisms. In the experiments with natural waters containing about 10 milligrams of organic matter per litre, the mollusk Dreissensia and a species of Leuciscus gave off more oxidisable matter to the water than was eventually taken up by them. These results seem to indicate that very little use can be made of the organic substances dissolved in natural waters. The experiments are being continued by the author and his final conclusions will be awaited with very great interest.

C. Juday.

J. le Gall. Statistique biologique et considérations sur la population harenguière de la Manche orientale et du sud de la Mer du Nord (matériel prélevé en 1929). Rev. d. Trav. de l'Off. des Pêches Mar. Tome III, fasc. 2, no. 10. Paris, 1930.

The leader of the biological laboratory at Boulogne s/m has for a series of years devoted a great deal of attention to the study of the autumn and winter herring in the transitional area between the Channel and the North Sea, and such continuous observations are of course the more useful the longer they are carried on. Here, after a rapid definition of the three herring "provinces" to be distinguished (Gris-Nez to mouth of the Somme, group I; mouth of the Somme to Cape Antifer, group II; and the Dijck-Sandettie region, off the Belgian coast, group III), the author proceeds to discuss the material collected during the autumn of 1929. Herrings were measured, scales taken for age reading and vertebrae counted, and in this way charac-

teristics for the herrings of the three areas mentioned have been obtained. From the measurements it was possible to calculate the average length of each year class of herrings.

Racial investigations. It appears from continuous studies that only the population of area II, south of the Somme, can be regarded as a pure, unmixed one; the average number of vertebrae and the frequency curve distinctly point to the characteristics of the East Channel herring ("type Manche") extending sometimes (winter 1928/29) along the Sussex and Kent shores. On the other hand, the area between the Channel and the North Sea is inhabited by a herring population, made up partly by a true North Sea race ("type sud de la Mer du Nord"), partly by a mixture of North Sea herring and Channel herring. The mixed population naturally occupies the boundary region between the two types, and as the southern North Sea type invades to a greater or less degree the transitional area between the Channel and the North Sea, probably according to hydrographic conditions, we get in different winters (1928/29 and 1929/30) different distributions. The present reviewer is glad to see confirmed his own hypothesis as to racial origin of herrings caught in the southern entrances to Dutch waters.

Year Classes. From a practical point of view we may, however, take the whole herring population in the regions named as homogeneous, for, apart from racial differences, it becomes more and more clear, as other investigators on the same subject also show, that certain predominant year classes and other deficient ones are generally the same, whether we take herrings (in a sufficiently large sample) from the waters south of the Somme or from Belgian waters. The continuity of the predominance of these year classes in consecutive years is indeed remarkable. So it is proved that in the winter 1929/30 the year classes 1921, 1922 and 1924 were everywhere predominant, to which the comparatively poor broods of 1923 and 1925 form a sharp contrast. Both herring types thus seem to vary in productiveness (or survival of larvae) to the same extent and in the same year and if this is perhaps to be expected in two races impinging on each other, the fact becomes of much greater consequence when we realise that, broadly speaking, the whole North Sea herring race shows the same fluctuations from year to year as its southern branch. Taking into account the obstacles connected with sampling the homogeneity of these results lends support to our belief that control over the yearly additions to the stock of herrings (be it some years afterwards) and, in this way, prediction of yield of the fisheries is indeed possible and trustworthy.

Growth. Comparing the average length of the year classes it is also to be noted that in all three regions investigated by the French author the growth of herrings at the same age is somewhat less than it had been in the previous winter. This also points necessarily to a more universal cause, probably to be sought for in hydrographic conditions acting either directly or indirectly. As Dr. Carruthers recently (this Journal, Vol. V, No. 2) drew attention to the greatly strengthened flow of the residual current from the Channel to the North Sea during the period from November 1929 to January 1930 (incl.), followed by a no less remarkable reversal of this current in February, we shall await with great interest the possible

effects of these unusual water movements on the productiveness of year classes of fish born in that winter, not only as regards the herring, but perhaps to a greater degree the plaice. This influence, if any, will become apparent two or three years hence.

M. Le Gall does not conclude his useful paper with any prediction about the future composition of year classes of herring in the winter 1930/31, but his results, tallying so well with those of other authors as Hodgson, Lissner, *inter alia*, are certainly something to be grateful for.

J. J. T.

W. C. Schroeder. Migrations and other phases in the life history of the Cod off Southern New England. U. S. Dept. of Commerce. Bur. Fish. Doc. 1081. Washington 1930.

In this important paper Schroeder is mainly concerned with the results of marking no less than 40,000 cod (in 1923—1929), but he also uses statistics of catch, observations of length-frequency and observations of scale structure. The choice of Nantucket Shoals, for marking some 18,000 of the specimens, enabled interesting and definite results to be obtained about the stock there, which is estimated to number from 3 to $4^1/_2$ million well-grown fish during the summer months. The stock of cod living on the Nantucket Shoals was found to be distinct from that living to the North and East of Cape Cod, only a very small percentage of the Nantucket Shoals cod straying to the North and East, and only a few cod marked to the North and East straying to the Nantucket Shoals. On the other hand a large proportion of the Nantucket Shoals cod were found to winter along the American coast to the South and West, as far as 200 to 300 miles. (Actually 2 specimens were recovered from a place in Virginia, at about 400 miles from the position of liberation). Of fish marked on Nantucket Shoals, the percentage recaptured North and East of Cape Cod was about 0.1, as compared with about 2.0 on other grounds, and about 1.0 on the Nantucket Shoals themselves. (A comparison made from the information of pp. 16—21, 31, 41, 42. Some of the cod from the North and East of Cape Cod also winter in the South, with those of the Nantucket Shoals, but these are shewn to be only a small proportion of the population wintering on the southern grounds.) Of the possible factors causing this migration, temperature appears to be the most likely, but the *incidence* of migration is not controlled by any particular temperature. The distinction of the stock North and East of Cape Cod from the Southern New England stock, is supported by a significant difference in the number of sclerite bands in the first zone of the scales.

There is also a summer migration from the Nantucket Shoals to the neighbourhood of the adjoining mainland (the "Chatham—South Channel" region), but this is less regular and only affects the larger fish (say >65 cms.). The fact that, during the summer, most of the cod on the Nantucket Shoals remain more or less stationary, was demonstrated from recaptures of marked fish, also the stability of the length-frequency curves and of the catch per unit of effort. It seems that the stock of cod on the Nantucket Shoals is mainly recruited by immigration, rather than by the settling of pelagic

fry. Georges Bank and the South Channel are thought to be the most likely sources. "The same individual cod may remain on Nantucket Shoals for 2 or 3 years, or, if some of them winter to the westward, they may be found on the shoals for several successive summers". But it is thought that on reaching a length of about 80 cms. the cod tend to leave the shoals for deeper water, where the population, we are told, may have from 10 to 20 per cent. of specimens of over 100 cms. long, a length represented on the shoals by less than 1 per cent. of the population. (The theory of emigration, rather than mortality, is supported by indications from recaptured fish, p. 51.)

The growth of cod was studied by means of length-frequency observations, scale examination and marked fish. The results are given as ranges, in inches, for "Southern New England Cod". The mid-points of the ranges given are as follows:—

Age in years	1	2	3	4	5
Mid-pt. of range (converted to cms.)	19	39	52	62	71

Schroeder's conclusions are reached as a result of a great deal of hard work, and careful analysis of observations and literature. There is much interesting detail that will repay the reader. Presumably it was self-denial that hid the interesting account of spawning, food and natural history generally, in a dozen pages in the middle of the paper (for these are not the principal theme). Page references to the text might have improved the summary, and the European reader would have welcomed one comprehensive topographical chart; but these are minor criticisms of an admirable piece of work. M. G.

Massimo Sella. Distribution and migrations of the Tuna (*Thunnus thynnus* L.) studied by the method of hooks, and other observations. Int. Revue der gesamten Hydrobiologie und Hydrographie. Bd. 24, Heft 5/6. Leipzig. 1930. (Article également publié en 1929: R. Comitato Talassografico Italiano Mem. CLVI). Traduction anglaise de Dr. L. W. Hackett.

Il arrive que le thon, voyageur et vorace, désarme lors de ses passages sur les pêcheries, les lignes trop faibles pour résister à de pareilles captures et dont il emporte, ferré dans sa gueule, l'hameçon. Ces souvenirs des pays visités ont pu être retrouvés sur le touriste lui-même, en des régions parfois lointaines, constituant de piquants témoignages de sa provenance. — L'identification de ces certificates d'origine permit au Dr. Sella, voici cinq ans, d'édifier son hypothèse du thon grand migrateur. Elle reposait alors sur un nombre assez restreint d'exemplaires et, de ce fait, certains se refusèrent à la prendre en considération. Aujourd'hui le nombre des hameçons découverts s'est singulièrement augmenté, vérifiant des itinéraires établis, en dévoilant de nouveaux. Fort de ce stock toujours croissant de pièces à conviction, Sella tire aujourd'hui de nouvelles déductions:

Treize hameçons méditerranéens attestent les migrations du thon à travers les différents bassins de la Méditerranée, du N. au S. (Malaga—Arzeu), du S. au N. (Tunisie—Adriatique), de l'W. à l'E. (Malaga-Tripoli-

taine), de l'E. à l'W. (Constantinople-Tripolitaine et Tunisie). Dans ces conditions il ne saurait plus être question de séparer l'espèce en groupes autochtones.

Vingt-cinq hameçons atlantiques prouvent le passage des thons à travers Gibraltar sur une large échelle.

Un hameçon espagnol retrouvé à Oslo établit le rapport entre le golfe de Gascogne et la Norvège et par suite entre la Méditerranée et la mer du Nord.

La "Méditerranée mer close" est ainsi mise en doute par plus de trente témoignages.

Le fait que les porteurs d'hameçons nord-espagnols se trouvent toujours être de gros poissons, permet à l'auteur de déduire que la côte cantabrique est fréquentée par de gros thons bien que les pêcheurs n'en capturent que de petits. — La découverte en Sardaigne d'un hameçon des Açores l'autorise enfin à affirmer l'existence de *Thunnus thynnus* L. dans cette dernière région où il n'aurait pas encore été rencontré.

Les diverses provenances des hameçons recueillis s'ajoutant aux régions déjà connues permettent de délimiter la zône de répartition du thon. Elle comprend la Méditerranée, et la moitié de l'Atlantique septentrional jusqu'aux Açores, de la latitude du Tropique au cercle polaire. Dans cette zone le Dr. Sella schématise ainsi les déplacements d'ensemble du thon: Un rassemblement en mai —juin dans la zone restreinte de reproduction (la Méditerranée et ses abords), — des mouvements successifs centrifuges en été avec dispersion des thons dans toute l'étendue de leur vaste habitat, — reduction de l'habitat à l'approche de l'hiver, — nouvelle migration vers le nord en mars—avril, mais d'amplitude limitée, — enfin en mai—juin le cycle recommence.

Dans ces mouvements de dispersion et de concentration un décalage est à noter des gros thons sur les petits, ces derniers présentant toujours un retard de quelques semaines. — Pour l'auteur, le rythme des migrations n'est pas influencé par des variations de salinité, les provenances des hameçons récupérés montrant en effet que l'animal peut fréquenter des eaux de salure très élevée (Cirénaique 38,5 $^0/_{00}$) ou très faible (Bosphore 18 $^0/_{00}$).

Après avoir ainsi caractérisé les migrations d'ensemble du thon, M. Sella cherche à renforcer la théorie d'une race unique par l'étude des caractères biométriques, et dit n'avoir pas trouvé de variations suffisantes dans ses mensurations de thons atlantiques et de thons méditerranéens pour justifier leur séparation en deux races distinctes. La similitude de croissance mise en évidence par l'examen des vertèbres sur 1800 individus, suivant la méthode de F. de Buen, fournit à l'auteur un autre argument de premier ordre. — L'hypothèse de Steuer sur l'existence possible d'une race de gros thons atlantiques et de petits thons méditerranéens ne doit donc pas être retenue.

Enfin l'auteur aborde la question des fluctuations de la pêche que la crise des dernières années plaçait au premier plan. A la suite de Neuparth, M. Sella a cherché à rassembler tous les renseignements statistiques possibles sur la pêche en Atlantique et en Méditerranée et, de ces données a tiré les conclusions que voici:

La pêche du thon subit en Italie et en Tunisie des fluctuations séculaires correspondant à celles vérifiées pour les mêmes périodes au Portugal, les unes et les autres se trouvant ainsi en correspondance avec les dernières fluctuations séculaires de la pêche du hareng dans le Skagerrak. — Les données statistiques interprétées suivant la méthode de Vercelli, mettent en évidence pour chaque thonaire des fluctuations périodiques secondaires assez régulières. — Ces résultats permettent de risquer des prévisions sur le rendement probable des thonaires et celles du M. Sella se sont cette année vérifiées.

En définitive il ressort de la note substancielle du M. Sella que l'auteur a su tirer d'une méthode élégante et logique d'importantes déductions éclairant d'un jour nouveau la biologie encore mal connue du thon rouge et pouvant être grandement utiles à l'industrie des pêches.

H. Heldt.

William F. Thompson and William C. Herrington. Life History of the Pacific Halibut. (1) Marking Experiments. Report of the International Fisheries Commission. Number 2. Victoria, B. C., 1930.

The present report forms the first publication of scientific results obtained under the terms of the convention between the United States and Great Britain for the preservation of the halibut fishery of the Northern Pacific Ocean, including the Bering Sea.

The migrations of the halibut in these waters are studied by marking experiments and the present report gives a full account of all details regarding the method of marking and the results of the experiments obtained up to the end of 1928. Due to the existing close season of three winter months, from the middle of November to the middle of February, the fishery on the spawning grounds has been restricted, but the total amount taken has not been reduced, as an equally great intensification has occurred on adjacent areas during the remainder of the year. When further regulations are to be considered it is therefore a question of the greatest importance to get information about the stock of fish on the various banks, about their migrations and the rate of recapture. It is true that all possible regulations are conditioned by the movements of the fish concerned, as the effectiveness of the regulations depends upon the migratory habits of the halibut.

The fish were caught by ordinary methods of commercial fishing and strap tags attached to the operculum of the eyed side were used. The first marking was done in 1925 and the total number of halibut tagged was 6,554 in the waters south of Cape Spencer and 5,281 north and west of Cape Spencer. The fish tagged on the former banks were nearly all immature, those on the latter mainly mature. The intensity of the fishery is especially high on the southern banks. The southern region showed a total return of 36.0 per cent. for the 1925 experiments and 31.7 per cent for the 1926 experiments in three seasons after tagging. In the western experiments, 7.8 per cent. were returned in the first season, the only one for which complete returns are available.

The migrations shown were very different for the southern and western

fish, and this difference corresponds to the condition of relative maturity. The immature fish of the southern banks were highly restricted in movements and differed greatly from the mature fish of the western grounds. About 92 per cent. of the immature fish marked moved less than 50 miles, and 96 per cent., less than a hundred, an average for all returns of about 22 miles. The dispersion increased slowly from year to year, but the bulk of fish remained on home grounds. On the contrary only 14 per cent. of the mature fish marked on the western banks moved less than 50 miles, and only 29 per cent. less than a hundred, — on an average about 250 miles, that is, more than ten times that of the distance of the southern fish. The conclusion is unmistakable, that the mature western fish migrate freely and extensively while the immature southern fish do not. In the present report all the returns of marked fishes are given in detailed tables, but they are summarized by statistical areas which are here defined for the first time.

There are many points of interest in the report which cannot be touched upon here, but the conclusions to be drawn from the results are that the western and southern fisheries are nearly separate biologically, as far as the commercial sizes are concerned, and that regulations protecting particular banks are desirable. In this connection it is of interest to note that five per cent. only of recoveries from the western experiments were retaken south of Cape Spencer, and but one fish from the south was retaken in the western region. A great deal remains, however, to be done by further experiments and it is with great interest that the reader learns that studies of racial characters, of differing growth rates, and of relative abundance in the several areas have been carried on and will be reported elsewhere. In the future it is hoped that "the marking experiments should become a really effective and much needed instrument in the control of the halibut fishery. It should be possible to follow the fate of the stock on any bank, its decrease through death, capture, and emigration, and its increase through immigration." As the results of the marking experiments are not yet finished, it is too early to form a judgment of its success, but there is every reason to believe that they will prove valuable and interesting, being the most important basis for future regulations concerning the Pacific halibut fisheries.

P. Jespersen.

L. Beaugé. La pêche à Terre-Neuve en 1929. Rev. Trav. de l'Office des Pêches Maritimes. Tome III. Fasc. 1. pp. 79—102. Paris 1930.

This paper is actually the 10th from the Office des Pêches Maritimes on this subject, not counting numerous popular articles in the trade paper "La Pêche Maritime"[1]). The theme of all the papers is the relation of the actual fishery to hydrological factors. This idea has not developed gradually, but sprang full-grown, like Athene, from the head of Le Danois

[1]) Notes et Mém. 35, 1924; Mém. Sér. Spéc. 5, 1926; Mém. Sér. Spéc. 7 (2 papers), 1927; Rev. Trav. Tome I, Fascs. 2, 3, 4, 1928; Rev. Trav. Tome II, Fascs. 1, 2, 1929; and the paper under review.

in 1924[1]), though probably partly due to the observations of HUNTSMAN in the Straits of Belle Isle in 1923[2]). Roughly speaking it is claimed that the cod mainly inhabits water of 3—5° C. of temperature (and about 33 $^0/_{00}$ of salinity, though less importance is ascribed to this), so that good and bad fishing years are due to variations in hydrology; and, as a corollary, favourable fishing grounds may be defined by use of a thermometer. The corollary is mainly BEAUGE's contribution.

In the paper under review, for example, the situation on the trawling grounds in March 1929 is described as very simple: There was no cod-water in the "Accores des Chalutiers". The comparative failure of the sailing vessels in May and June (1929) is explained by the low temperature of the bottom water.

The thesis is reiterated in detail in the 10 papers referred to, which contain many observations of temperature and salinity, to form the basis of the explanations of the variations in the fishery. The nomenclature of the different kinds of water has been somewhat confused. BEAUGÉ only speaks of three kinds (Tome I, Fasc. 2, p. 35): Continental, including Laurentian and Labradorian, S $^0/_{00} < 33^1/_2$; Atlantic, S $^0/_{00} > 35$; and Slope water, which is a mixture of the other two. The "Bank Water" of BJERKAN (Canad. Fish. Exped. 1919, p. 357) and SMITH (Ice Patrol Rep. for 1922, p. 95), S $^0/_{00}$ 32—33, was considered by LE DANOIS (1924, p. 18) to be identical with "Continental" water, and BEAUGÉ does not mention it at all, calling the water normally covering the banks, Labradorian (loc. cit., p. 37). Since SMITH writes of the water on the Grand Bank as having a very definite identity, it is a little disturbing to find BEAUGÉ omitting it from his system altogether, without comment on SMITH's observations.

The papers contain many interesting essays in hydrology, such as one in the paper under review on the effects of clefts in the continental plateau, p. 84. Another is the paradoxical theory that in years of insufficiency of Polar water the temperature is unduly low on the bottom. The explanation is apparently that in years of insufficiency of the Polar discharge the "cabelling", occurring at the meeting of cold and warm water, takes place on the Grand Bank itself, instead of further to the southward, as normally occurs.

There is one very serious general criticism of BEAUGÉ's hydrology:— The French observations are not in fact the only, nor the principal, hydrological observations that are made in the region. Every year the Ice Patrol reports contain abundant material, by which the French observations could be checked or supplemented[3]). Yet, in these papers of BEAUGÉ, there is almost no reference to the Ice Patrol reports, and it is left to the reader to know that the Ice Patrol reports are available, and, if he has the leisure, to find out for himself whether the American and French observations agree or disagree, and whether BEAUGÉ is in any way indebted

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[1]) Loc. cit., 1924, p. 33.

[2]) First published in a lecture, "The Ocean around Newfoundland", printed at St. John's, Nfld., in ?1924.

[3]) Treasury Dep. United States Coast Guard Bulletins. Washington.

to the Ice Patrol observations, as he certainly should be, in forming his conclusions.

But the most important point of all is that there is no way of checking Beaugé's claims, as to the success or failure that might attend the fisherman who accepts the idea that cod-water is defined by the temperature of 3—5 degrees. The papers are scattered with isolated references to good or bad fishery in particular water, as on p. 101 of the present paper; but such remarks are hardly sufficient to convince us that these audacious claims are justified. On page 203 of Tome II, Fasc. 1, there is a chart of part of the "Accores des Chalutiers", inscribed with a number of figures representing good cod catches; and all the inscriptions, whether for small numbers or large, lie between the (100 metre) isotherms of 3 and 5° C. The data of positions and captures were obtained from captains by wireless; and it is not clear why, at the same time, observations of poor catches might not have been obtained and plotted, to see whether they lay in the zone of "cod-water" or not. As a matter of fact the catches inscribed vary from 1 to 31; (we are not told what the unit of measurement is). Without evidence from poor hauls the chart is worth little, and Beaugé's italicised comment that "they are all included in the zone of cod-water" is of no significance. Then, on pages 208—210 of the same paper, there is a long table shewing the results of fishing, along with simultaneous observations of temperature. It is disappointing to find, however, that the catches include all species of fish, and that sometimes they included enormous quantities of *Sebastes* and *Urophycis*, so that the much-desired correlation. of cod catch and temperature cannot be attempted.

This is not to say that Beaugé's thesis is regarded as wrong. On the contrary it seems likely to be right, but it is impossible to accept it, until data are given from which we can judge approximately the proportion of cases in which fishing operations yield results in accordance with the theory. M. G.

R. Rallier du Baty. La Crise de la Pêche au Chalut. La Nature, No. 2840. Paris 1930.

M. du Baty describes the history and the present plight of the deep-sea trawling industry in France. In 1893, the French trawler owners, seeing the English trawlers making large catches of hake off the coasts of France, bought similar trawlers, and commenced a lucrative fishery. The fishing grounds on the shallower coastal portions of the continental shelf were soon fished out; trawlers had to go further and further afield for hake; and, at present, even the fishing grounds along the edge of the deep water are yielding diminishing catches. Lorient, La Rochelle and Arcachon are in a sorry plight, and, if Boulogne has suffered less, it is because she is less dependent on the hake for the welfare of her industry.

M. du Baty emphasizes the change in the nature of the hake fishery, which has followed more and more intensive trawling. Apart from the seasonal irruption of the hake on to the shallower banks, the hake fishery is now a deep-sea fishery all the year round, and ships capable of towing efficiently the gear, with its great weight of warp, and skippers with the

knowledge and skill to work the very uneven slopes successfully, are at a premium. The difficulties of this fishery are well-known to English skippers. There are many places, on the edge of the deep water, where it is impossible to tow for long on a straight course, and a constant and skilful watch must be kept on the warps, to avoid towing off the bottom, on the one hand (when, as M. DU BATY rightly points out, it will take no fish) and coming up on to a bank, with its risk of destroying the gear, on the other. Many French trawlers (and English trawlers also) are adopting echo-sounding gear to help them, but this will find its greatest usefulness only when the slopes are accurately surveyed and charted.

The cause of this diminution in yield, and of this change in the nature of the hake fishery, is due, M. DU BATY thinks, to over-fishing, and possibly to changes in the sea bed and the overlying water, due to trawling. He compares the yield of the trawl fishery generally with that of the pelagic fisheries. The yield of the trawl fisheries has progressively declined, but can this be said of the pelagic fisheries, he asks, rhetorically. Even the masses of "coral", which grow in the deeper water, and which once formed the refuge of multitudes of "sedentary" hake, are now being destroyed, so that only "migratory" hake, whose appearances are short and fleeting, are there found. The adoption of the Vigneron-Dahl trawl, which he figures and describes (comparing it with the otter trawl and the "chalut-boeuf"), postponed, for several years, a crisis, which once again faces us.

M. DU BATY calls, in fact, for "rationalisation". The French industry must break with the traditional lines of English ships and methods. New and bigger vessels must be built, capable of fishing at 1500 metres, if need be. Accurate and detailed charts of the slopes at the edge of the deep water must be put at the disposal of the skippers, with improved gear and appliances, both technical and oceanographical, for working them. The existing grounds must be more intelligently exploited, and extended into deeper water.

This is admirable advice; but the reviewer must join issue with the author on some other points. For example, the English hake fishery, at least, cannot be said to have shown a progressive decline in yield in the last thirty years. The situation seems to have become stabilised somewhere about 1909, and, since then, the fishery has shown fluctuations comparable with those shown by all intensive fisheries, not excluding pelagic fisheries. There has been a continuous decline in the proportion of bigger fish, but this is the inevitable consequence of intensive trawling. The concentration of the hake in a comparatively narrow strip, especially in winter, along the edge of the deep water, makes them peculiarly vulnerable. We find ourselves, at present, in a period of depression, such as we had in 1923, and the sentiments expressed in this article were often heard then. If the past is any guide to the future, there is little reason to believe that this depression is permanent.

Further, it is probable that the fishery is already prosecuted to the maximum depth at which a profitable haul of hake is to be expected. The reviewer has witnessed probably the deepest hauls ever made on a commercial scale — between 400 and 600 fathoms depth. Hake were not

taken beyond about 350 fathoms[1]), and this depth is already within reach of many trawlers.

The author's remedy, in fact, is actually being applied slowly and cautiously; to apply it in the drastic fashion he advocates would require, under existing conditions, little less faith and courage than that required by the Galilean fishermen, whose plaint, that they had toiled all night and had taken nothing, so fitly and finely opens this article. C. F. H.

H. Lissner. Monatskarten zur deutschen Treibnetzfischerei 1929, Ber. d. deutsch. wissensch. Komm. f. Meeresforschung, N. F. Bd. V, Heft 3. Berlin, 1930.

It was a good idea which suggested the collection of monthly records of the drift-net fisheries for herring in the North Sea, as has been achieved for the fourth time by the well-known German investigator. On a similar principle to the "Squares" used in English statistics, indicated by letters and numbers, — with this difference, however, that these squares proved much too large for the purpose in hand, so that each of them was subdivided into nine smaller ones — each rectangle shows month by month both the number of hauls and the average catch of herring in crans ("kantjes") on separate charts, so that we may see at a glance, where in a particular month the fishing was most intensive and where also it proved to be most prolific. This is a most practical way of plotting the generally patchy herring shoals for further study; if indeed hydrographic conditions have any causal connection with this concentration of ripening and spawning herrings, Lissner's charts should make it easy to bring such connection to light. Salinity and temperature conditions are, however, only investigated on broad lines, and it would be an advantage if fishermen themselves were generally provided with simple means of determining the hydrographic conditions and, as an alternative, the character of the plankton during the actual fishing time, and really did avail themselves of such aids! As long as this is not the case we have to be content with the valuable information Lissner's meticulously drawn charts give us. Indeed we intend to start such work in Holland also.

The paper begins with statistics of a general nature about the production of the herring drift-net fisheries of countries around the North-Sea, the vessels used in these fisheries and the weekly records, during the seasons of 1929 and 1928, of the catch per lugger and per trip. A table showing monthly fluctuations of the landings (1929 and 1928) presents the usual irregular curve, with a tendency to fall in the middle of the season and again before the great autumn fishery near Yarmouth starts. The monthly charts above referred to, from July to November, are particularly instructive and show the time-honoured shifting of fishing regions as the summer draws on. Records were obtained from 245 trips out of a total of 662. Gradually as the season advances, the characteristically scattered nature of the fishing, which is particularly apparent in the month of August in the slack season, changes to the concentration of the vessels in the

[1]) See this Journal, Vol. III, No. 1.

"deeps" off Yarmouth. The value of records like these is the demonstration of occasional, comparatively big catches in such regions as are normally considered useless for the season, as, for example, the September fishing at Bressay Shoal, at a time when most luggers concentrate towards the Dogger Bank. The records for December are too scanty to be included in the charts. The author concludes with a reference to a prediction, made elsewhere (Fischerbote 1930, p. 180), as to the chances for the drift-net fisheries in 1930, a statement which in the meanwhile has already been partly confirmed. J. J. T.

William F. Thompson and Norman L. Freeman. History of the Pacific Halibut Fishery. Report of the International Fisheries Commission. Number 5. Vancouver, B. C., 1930.

In very old days the halibut undoubtedly was already an important food for the Indians living along the coasts of the Pacific. Many of the explorers of the eighteenth century, e. g., Captain Cook in 1778, mention the great number of halibut caught by the Indians, and really their fishery had a well-developed technique and until late years they have continued to use their own large hooks. From the description of the Indian methods, it will be understood that this people, as their fishery had a high degree of efficiency, could fish in considerable depths and land fish in astonishingly great quantities.

The commercial fishery of halibut began first about 1888—1892, when the final connection was made with the east by the completion of the railroads across the continent. White men learned the locations of the more distant fishing banks of the Indians and a good deal of the fish was purchased from this people. The vessels used were small sloops and schooners carrying as many as three dories in the waist of the vessel. The total quantity of halibut landed along the Pacific coast amounted in the year 1889 to 1,777,250 pounds. In the last years of the nineteenth century the fishery developed to a much higher degree, and the operations were principally carried on from steamers having eight to twelve dories stowed on the stern. With the adoption of dories, the use of the vessels for fishing, and the bettering of methods for handling the fish, deeper water was tried. The fishermen extended their knowledge year by year as the necessity for new banks arose.

Up to the year 1909 or 1910 the fishery and the fishing fleet had been growing, especially since the use of power became general, but the fish in protected waters began in about 1905 to be scarcer and scarcer and some of the best fishing grounds began to show a decline, both in quantity and size. In 1910 there occured a great shift from an inshore to a truly deep-sea fishery. In the following years the building of larger vessels allowed expansion of the fishery to deeper and to more northern waters. The statistics show that the ability of the fleet to reach new banks and to tap new sources of supply plays a greater part in the maintenance of the total yield than does the increasing efficiency of the fishermen and their methods. In 1910 and 1911 are to be found the first statistics as to the total landings for the entire coast, and it has therefore been possible to use this year as

a basis for comparison with the present conditions on the older banks. In 1912 appeared the first of the halibut vessels convertible to purse seiners, hence of use not merely for halibut fishing but for salmon as well, and in after years this style of vessel became common in many places. At the same time several vessels were fitted out as floating cold storages, but these did not succeed sufficiently well to result in the permanent use of such ships.

Since 1910 there has been a great expansion of the fishery both to the south and to the north, but in 1914 and 1915 an overproduction took place with the result that prices were very often too low to be profitable. The outbreak of the great European war in 1914, however, brought the overproduction to a halt in the following years and the total landings fell while prices rose. There was a period of years from 1915 to 1923, or thereabouts, when new banks were not so eagerly sought, but the fishing methods were steadily improved. In 1921 the first Diesel engine was installed in a halibut vessel, but by 1923 a great many installations had already been made and now only a single steamer takes part in the halibut fishery.

Hereafter engine power was applied in many ways to render operations more efficient and to enable the vessels to go farther for their catches. It was not until 1923 that the exploitation of the banks west of the Gulf of Alaska was begun by the large schooners equipped with Diesel engines, but the importance of this distant fishery has steadily grown. At the same time the treaty imposing a close season of three months, from November 16th to February 15th, was signed. The larger vessels, which were not dependent upon the banks most affected by the closure, have therefore extended their operations to the more western banks, where they could operate throughout the season.

In this historical account of the development of the fishery of the Pacific halibut the authors have collected much valuable information giving the necessary historical background for the understanding of the present condition of the banks, which certainly is of the greatest importance for proper regulation. We find an interesting account of the present position of the fishery, but the reviewer would find the description still more useful if the authors had given the statistical data of the fishery since 1916 in more detail. P. Jespersen.

Rudolf Kändler. Die Kultur der Auster. Handbuch der biologischen Arbeitsmethoden, Abt. IX, Teil 5, Heft 5, Lieferung 333. Berlin 1930.

No claim is made for this work to be regarded as a reference volume with encyclopaedic properties, wherein may be found full details of present day oyster culture in all those countries where it is practised. The author's aim is rather to give within a moderate compass the essential features which distinguish the methods of different countries, considered in relation to climatic and hydrographic conditions, to the requirements of different species of the oyster, and to the early histories of their natural beds. Such histories are mostly stories of reckless exploitation and depletion which led either to abandonment or to importation of oysters from other grounds, or to elaboration of methods for assisting the natural production of seed

oysters, and their growth and fattening for market. Attempts to apply the methods of one country to culture in another, without regard to local conditions have never resulted satisfactorily.

The author gives a short account of the biology of the oyster before proceeding to culture methods characteristic of the various countries. Descriptive sections devoted to France, Belgium, Holland, Great Britain, Germany, Denmark, Norway, and Italy include a remarkable range of methods and conditions. The most important production among European countries is in France, with a highly developed system of limed spat collectors accessible at low water, cages for protecting young oysters after detachment, and claires for finishing the product. Of considerable interest is the progressive supplanting of *O. edulis* by *O. angulata*. Of the countries further north, spat production is most irregular in some, and in others is negligible, so that the industry consists partly or wholly of raising imported seed for market or even of merely conditioning for market. In the absence of significant tides in the Mediterranean, and in the Norwegian basins on account of peculiar hydrographic conditions, spat collection in both these countries is effected by means of brushwood suspended from ropes stretched between groups of poles (Italy), or supported by floating barrels (Norway).

In addition to culture in European countries, the author describes that in the United States and Japan. Improved methods of spat collection have recently demonstrated how production may be increased in the Northern Atlantic coast of the States, where setting of spat shows considerable variation from year to year. The most important new method appears to be the use of shell cultch placed in wire netting bags, which may be piled up on ground unsuitable for covering with scattered shells. The Pacific coast has not only the native oyster (*O. lurida*), but also *O. virginica*, and *O. gigas*, introduced from the Eastern States and from Japan respectively, each requiring appropriate methods. Only the native oyster reproduces in significant numbers on the Pacific coast, however. A striking feature of Japanese oyster culture is the very extensive use of bamboo sticks, arranged in rows of clusters on the tidal flats for catching spat. The spat remains to maturity on these sticks, growth being very rapid. For export to America shells are used for catching spat. There are resemblances between the methods used in Japan and that in New South Wales, where mangrove sticks take the place of bamboo in certain areas, while in others slabs of stone serve as collectors. The inclusion of some mention of conditions and methods developed in Australia would have added to the interest and comprehensive scope of the present work. After the descriptive portion, as outlined above, there follows a useful summary of methods in tabular form.

The last section is devoted to oyster production in closed ponds or basins. The numerous earlier attempts, though sometimes successful, have had no permanent outcome. More recent work on scientific lines in England, Denmark, and Germany (Heligoland), and in the United States, is described with a considerable amount of detail. The experiments in England are now concerned mainly with the provision of an adequate supply of food for oyster larvae in large closed tanks. At Heligoland the best results

have been obtained in laboratory experiments with running water, the larvae being retained in small vessels by means of sand filters. In the United States two methods of artificial culture have been worked out on a laboratory or small hatchers scale, one with constant renewal of water, the other with daily changes, there being special arrangements to prevent loss of larvae. Neither method, however, shows any promise of economic importance.

The whole work is illustrated by over fifty photographs, diagrams, and maps. The author is to be congratulated on his selection of material which has resulted in a work of much interest and value. H. P. S.

A. Hagmeier und A. Schubert. Untersuchungen über die Biologie der Auster. Nr. 4. Die Austernbrut im Wattenmeer. Wissenschaftliche Meeresuntersuchungen, N. F., Abt. Helgoland. Bd. XVIII, Nr. 1. Oldenburg, 1930.

The present paper deals with investigations made in the summer of 1928 on certain oyster problems in the shallows east of the island of Sylt, off the west coast of Schleswig-Holstein. It is a continuation of Kändler's work in 1926 and 1927 (reviewed in Vol. V, No. 2 of this Journal). In order to investigate the possibilities of restoring former oyster beds to productivity in this locality, Dutch oysters were laid down on the Ellenbogen Bank at the entrance to the wide inlet between List and the mainland. The north-eastern portion of this inlet lies over the Danish boundary.

Hydrographic observations similar to those made in 1926 and 1927 from June to October show that the salinity remained at about 30 per mille throughout the summer, and did not vary more than 2.4 per mille. The mean daily water temperature slightly exceeded that of the air, and reached a maximum of just over 19° C. in mid-July. A comparison of temperature conditions is made with those found by Prytherch in Milford Harbor, Connecticut, where the relation between air and water temperatures and the mean air temperature for a considerable period of years is known. The conclusion is that summer water temperatures in the Sylt shallows are normally below the minimum spawning temperature for the American eastern oyster, viz. 20°—21°, and that any attempt to introduce this species for the purpose of breeding would therefore be useless. Indeed, the temperature has often been barely high enough for satisfactory production of spat from the European oyster.

Plankton samples, totalling 44, mostly of five minute hauls at the surface with a fine net, were taken at seven or eight stations distributed over an area eleven kms. long. These were taken on five sampling expeditions during the spawning season. Except for a first catch of nearly four thousand early larvae on July 22nd near the spawning bed, the catches exceeded one hundred larvae only on one other occasion, in September. Thirteen catches in July and August contained no larvae; the others varied from two to sixtyeight larvae. The proportion of ready-to-set larvae, apart from two out of seven at a station furthest removed from the spawning bed, averaged only about five per cent. These older larvae were confined to nine of the samples. By comparison with Kändler's figures for occur-

rence of larvae in 1926 and 1927 it is evident that the 1928 spawning season was late. An examination of the mean monthly air temperatures for May to September shows that they were lower in each of these months than the average figure for the month over a considerable number of years; the differences ranging from 0.4° C. (August) to 2.2° C. (June). In contrast with the observations of Prytherch in Milford Harbor, and Nelson in Barnegat Bay with *Ostrea virginica*, there were no marked differences in numbers of larvae at different states of the tide, either in 1928 or the two previous years. No data relating to tidal currents are included in the present paper, however, whereby a comparison could be made with conditions in those localities. No spat was found on shells put out in special containers at mid-August in places where advanced larvae had been found the previous summer, or on shells dredged up elsewhere in October. There were, it appears, as in the previous years, insufficient larvae of setting size to produce any significant spat.

With this paper is included a brief report relating to the 1929 season. During that summer there occurred a few opportunities for taking samples over the Ellenbogen Bank. The most larvae caught in five minutes were taken on August 10th, and amounted to 18 only. Adverse conditions during the previous winter reduced the number of spawning oysters to a number estimated at one tenth of those present in 1928. The mean monthly temperatures in June and July were below the average. There were no facilities for ascertaining if any spat had settled, as the local oyster company had ceased to operate.

In summarising the conclusions to be drawn from all the Sylt investigations, Dr. Hagmeier discusses means of re-establishing the oyster fishery. The production of larvae from imported Dutch stock, and their growth to setting size was demonstrated, but they were not present in sufficient numbers to give rise to a spat fall of any value. The growth of these imported oysters was satisfactory, however. The solution seems to be the establishment of a business for growing oysters for market from imported seed, such that in time there would always be during the summer an adequate reserve of spawners to produce spat when conditions are favourable. He draws attention also to the possibilities which further research may open up for production of spat in closed basins. It may be noted that only when the value of the oyster is high, and where natural production is very irregular, is artificial production likely to have an economic value. In the case of the Northern Atlantic coast of the United States, though artificial methods have been devised with some success for raising oysters under controlled conditions in small hatcheries, it has been made clear that the only practical way at present of dealing with a decline in production is by improved methods of natural spat collection. H. P. S.

Interdepartemental Committee apointed by the Minister of Agriculture and Fisheries and the Secretary of State for Scotland to enquire into the Crab and Lobster Fisheries. Report on Crabs. London, 1930.

This paper gives very complete information, essentially in statistical form, as to the crab fisheries of Great Britain. At 39 English ports stati-

stical data were obtained regarding the number of persons engaged, the number and types of boats, and the quantity and types of gear employed in the crab fishery. Indications as to the increase or decrease of the fishery are given by statistics, amongst which those for Scotland containing the average numbers of creels used, the average numbers of crabs landed, and their average value, summarized for periods of five years are particularly interesting. These statistics are of very great value, especially in view of the recommendation to make similar inquiries in 1932 for the purpose of obtaining thorough information as to the general trend of the fishery. Valuable biological information is to be found in the statistics regarding the measurements of ♂ and ♀ crabs from the market and from unselected samples, and the determination of their ratio, and the time of ecdysis. All of these investigations were carried out in order to learn if it was desirable to take measures for further protection than is now afforded by the Oyster, Crab and Lobster Act of 1877 and the local byelaws.

The landings in England and Wales — from which those of the English East Coast are the most important — taken as a whole show continuous increase (in numbers), and from 1923 onwards they are higher than in the prewar years (1911—1913, 5.4 million; 1919—1922, 4.6 million; 1927—1929, 6.5 million, per annum). From this, however, it may not be concluded that the number of crabs in the sea is also increasing, as it is not known if the intensity and the activity of the fishery (through the introduction of motor craft) have not changed. From the fact that the average breadth of the crabs in the most important districts (Eastern, North Eastern and Northumberland) is rather near the "legal size" (mostly 5.2—5.3 inches, the legal size being 4.25 inches), while in another district (Sussex) the average size is above 6.3 inches, one is inclined to conclude that the intensity of fishing in the former districts is very high.

By raising the legal size the immediate losses for the fishermen in various districts would be very different, an increase to $4^1/_2$ or 5 inches, for example, giving losses as high as 21 % or 51 %. These would of course be of a very serious nature, and since the yields of the fishery are not yet falling off a general increase of the size limit is therefore not yet recommended. For the same reasons further protection of the soft crabs and the introduction of a close season during the time that great numbers of soft crabs occur is not proposed. Although the Committee is of the opinion that in this period much damage is done by the destruction of soft crabs, on this point also an optimistic view is maintained.

We now come to those parts of the investigations which are also of direct biological interest. Taken as a whole they showed that the sex ratio $\frac{F}{M}$ was 111 (111 females to 100 males). There are, however, great differences in the various districts, the ratio in Sussex being 66 and in the North Eastern district 157. (Is there perhaps some agreement here with the observations of Bjerkan on the crab population of the Norwegian coast?) Soft crabs proved to occur in maximum abundance in August. In regard to size it was found that the crabs of the east coast are relatively small; the Committee is of the opinion that this fact may be due in a large measure to their slower growth, and not merely to an

excessive intensity of the fishery. Further investigations on this subject, in connection with size distribution and migration, would be of great importance biologically and also in relation to the size-limit. On this point there are yet large gaps in our knowledge.

In an appendix ELMHIRST gives notes on the growth of lobsters, based on rather a small number of observations in the aquarium. From these it is concluded that before maturity females grow faster than males, and after this, as is well known the reverse is the case. Consequently males and females are of equal size at about 10 years old. It would be interesting if such an intersection of the growth lines of males and females at an age of about 10 years should find further confirmation from observations in nature also. B. HAVINGA.

J. F. G. WHEELER. The Age of Fin-Whales at Physical Maturity with a Note on multiple Ovulations. Discovery Reports. Vol. II. pp. 403—434. Cambridge 1930.

In an earlier report Messrs. MACKINTOSH and WHEELER dealt with "Southern Blue and Fin-Whales". In this paper, recently reviewed in this Journal, the authors dealt with the biology of the whale up to sexual maturity at the age of two years. Their material enables us to understand the growth conditions of the whale, and they have been able with fair exactitude to construct a growth curve for the foetus, the suckling calf and the young, sexually immature animal. After reaching the period of sexual maturity the results achieved by the authors were not, however, so sure and their conclusions regarding the length of life of the individual were, on account of the material then at hand, very speculative, as they themselves point out. At that time they relied chiefly on the number of corpora lutea in the ovaries, but they had also begun the investigation of the degree of physical maturity by means of the fused or unfused condition of the vertebral epiphyses.

This work has been continued and the result has been given in the above mentioned treatise by Mr. WHEELER.

The fusing of the epiphyses with the centra of the vertebrae takes place gradually, the intervening cartilage layer becoming thinner and thinner and ultimately disappearing entirely. After ankylosis a whitish line indicates for a time the join, but finally this also disappears. When the ankylosis is complete, the animal is physically mature and all growth in length ceases. Other investigators have found that the ankylosis begins at both ends of the column and proceeds forwards and backwards towards the middle. The author found that the ankylosis begins, no doubt, at both ends, but from the anterior end it does not reach much beyond the cervical vertebrae so that ankylosis is completed among the anterior thoracic vertebrae.

The author has therefore generally examined the following vertebrae:— one posterior lumbar vertebra, one middle lumbar vertebra, one posterior thoracic vertebra and one or two as far forward as possible i. e. the 2nd, 3rd or 4th thoracic vertebra. In this way a general idea has been obtained of the progression of the ankylosis. The author, along with Mr. F. D.

Ommanney, has examined nearly 300 female fin-whales and nearly 200 of these were sexually mature animals.

The individual length has not proved to be a certain indication of the age, as the smallest sexually mature female fin-whale was more than 2.5 metres shorter than the largest immature female fin-whale, and there also appears to be a great variation in the length at physical maturity. One whale measuring 21.05 metres and a number only slightly longer were physically mature, while the author has examined whales measuring over 23 metres where the epiphyses was not yet fused to the centra.

Only females were examined, for the object was to get data for comparison with the coincident investigation of the condition of the ovaries and the number of corpora lutea. Methodically the procedure in this investigation was the same as before but the author has taken up for renewed discussion the circumstances in regard to the formation of, and the persistence of, corpora lutea in the ovaries. This has led to the theory set forth in the previous report on "Southern Blue and Fin-Whales" being slightly — though in principle, immaterially — modified.

The results of the investigations of physical maturity and the number of corpora lutea have been arranged in synoptic tables and curves. Of 105 whales with less than 15 corpora lutea there were only 2 with, respectively, 11 and 12 corpora that were physically mature, with the epiphyses fused to centra; and of 66 whales with more than 15 corpora lutea there were only 4 physically immature. Consequently while the number of corpora lutea and still more the fusing of the epiphyses to the centra have no close relation to the length, their mutual relation is very clear. The age of the whale that has attained physical maturity must therefore be that which is required for the accumulation of 15 corpora lutea in the ovaries.

It is easy to understand from the relation between the physical maturity and the number of corporea lutea that the latter must stand in a certain relation to the age. In their number there appears a tendency to a grouping about definite figures, and this is explained thus: We take for example a group of whales in their first sexual season. At the close of the season the minimum number will be a functional corpus luteum and the whale will be pregnant. The maximum number of corpora lutea will show the maximum number of ovulations that are possible during one season. Among social animals with extensive, more or less simultaneous migrations, the maximum of successive pairings with the consequent fertilizations will occur in the course of a comparatively short time. There will therefore be a tendency towards the above mentioned grouping about a definite number of corpora lutea. Next season these animals will be lactating, and normally no new corpora lutea are formed. Thus the accumulation of corpora lutea will be continued every other season. This also appears in a graphic statement of the frequency of corpora lutea. There are distinct maxima with 1, 7 and 11 and an indication with 18 and 22 corpora lutea for the season 1929—30.

The whales may be grouped round these maxima: Group I including whales with 1 to 4 corpora, Group 2 with 5 to 9, Group 3 with 10 to 14, Group 4 with 15 to 19, and Group 5 with 20 to 24 corpora lutea. On the assumption of one young every other year, each of these groups includes

two year classes, the pregnant and the lactating animals one year older. Consequently we have here a means of estimating roughly the number of females in each year class.

There is an essential difference between Group 1 and the other groups as most of the animals have already become pregnant at their first ovulation. This the author explains by the fact that the young animals have a somewhat different migration and possibly find themselves in waters where the pairing takes place earlier than that of the older animals.

In the graphic representation of the number of corpora lutea we have therefore a means of determining the age of the females with a certain degree of probability up to eight years after sexual maturity or in all to the age of ten, when we remember that the whale requires two years to attain sexual maturity. We saw that the physical maturity, characterized by a complete ankylosis of the column, occurred simultaneously with the presence of about 15 corpora lutea in the ovaries, that is to say between what we call groups 3 and 4. Consequently the physical maturity should be complete from 4 to 6 years after the sexual maturity, or from 6 to 8 years after birth. If the average increase in the number of corpora lutea is 4 each year, then a fin-whale captured last season was at least 20 years old. The largest and heaviest ovaries were found in an animal with 18 to 20 corpora lutea and this suggests, possibly, that the maximum of reproduction is over at the age of ten. There is, however, no typical sign of a climacteric.

In the "Note on multiple Ovulations" the author calls attention to the peculiar circumstance that when several ovae are released at the same time, there will be just as many large functional corpora lutea as foetuses and that a corpus luteum perhaps reflects the fate of its own released ovum. There is, however, but a very small percentage of whales that have multiple ovulations and more than one foetus.

The author has succeeded in presenting his results in a clear and convincing manner and we now perceive that the theory he and Mackintosh advanced in their previous paper, that it should be possible to determine the age of females by means of the number of corpora lutea in the ovaries, has received considerable justification. Also this is the only means we have at present. We venture to hope that the author will continue with these interesting investigations and will make new and equally important contributions to our knowledge of the growth and age of the whale.

Johan T. Ruud.

A. B. Keys. The Measurement of the Respiratory Exchange of Aquatic Animals. Biological Bulletin, Vol. LIX (No. 2), pp. 187—198. Lancaster, Pa., 1930.

The measurement of the gas-exchange of aquatic animals has assumed so important a place in physiological and ecological studies that a critical review of the various experimental methods employed, and the embodiment of their salient advantages in a new one, will be read with interest by all workers on the subject.

The methods in vogue are grouped by the author into three main

classes:— a) in which the animal is kept in a closed vessel, from which samples are removed periodically for gas-determination; b) in which REGNAULT'S principle is employed, the addition of oxygen to a closed water-system compensating for its removal in respiration; and c) in which the respiratory conditions are kept approximately normal by a current of water, of which the gas-content is ascertained before and after passage through the experimental chamber.

The first method was tested with four types of apparatus, using *Fundulus* as the test-animal, but even after due allowance for sources of error, consecutive results were found to differ by as much as 15 per cent.

The second method was not examined, the author apparently accepting KROGH'S strictures as to its complications and shortcomings. The arrangement proposed by CLARK (Nature, 29th March 1930) had not come to the author's notice — to the reviewer it appears to be sound and elegant, and to be especially applicable to the smaller aquatic invertebrates.

The third method, in the form used by EGE and KROGH, is criticised on the ground that stratification interferes with proper sampling of the water, while further error is introduced by the narcotisation of the experimental animal. These objections are held to be overcome by the method described.

Reference must be made to the original paper for details of the apparatus, but the principal features in which it differs from others of the type are a) the arrangements for maintaining steady flow, with constancy of head and back-pressure; b) the careful adjustment of the capacity of the respiration-chamber to the size of the animal under investigation, and c) the simplified and improved arrangement for collecting (or by-passing) the efferent and control waters.

The apparatus, as described, appears to be especially well adapted to serial observations, and numerous tables of oxygen uptake values, for several species of fishes, are given. All agree in showing a falling-off of oxygen consumption throughout the first five or six hours, but, thereafter, consecutive determinations differ by as little as 2.8 per cent. on the average. The metabolism, at this stage, may safely be regarded as "standard" for the apparatus and conditions, but further investigation is needed before the author's claim can be substantiated, that the "basal" level is then attained, at least in the sense that that term is employed in mammalian physiology. J. R. B.

STANISLAW SKOWRON. Über das Leuchten des Tiefseefisches *Chauliodus Sloanii*. Biologisches Zentralblatt, Bd. 48, Heft 11. Leipzig 1928.

Whereas the structure of the luminous organs in deep-sea fish has been exhaustively described, observations on the luminescence of these organs are rare, for the good reason that few students in this field have the opportunity of securing living deep-sea fish.

In the short note under review, Dr. SKOWRON sets down some observations, which he made at the Biological Station at Messina, on the luminescence of *Chauliodus Sloanii*.

The fish, when swimming about freely, showed one kind of luminescence

only, namely, a faint continuous blue light on the belly. Mechanical stimulation, however, caused a wave of luminescence to spread rapidly from the point stimulated to other parts of the body bearing luminous organs, the contour of the fish being outlined with light after a comparatively powerful stimulus.

The simple organs, which consist of gland cells only, and which are found thickly strewn in the dermis of the back and belly, only show a short luminescence immediately after stimulation, and the same applies to the complex, flask-shaped organs, equipped with lens and reflector, found near the eyes and in two rows near the ventral line of the belly. The latter, however, remain luminescent somewhat longer, though even then for a few seconds only. The continuous light on the belly is unaffected by stimulation, and SKOWRON considers it probably due to the cup-shaped organs which occur in groups of four or five on the mid-line of the belly.

As the fish becomes moribund, the continuous light is the first to disappear. The other organs can still be made to respond to powerful stimuli, the organs on the lower jaw and at the base of the tail retaining this faculty longest. The organs of a dead specimen cannot be made to luminesce, even when removed from the fish and triturated in suitable media.

Luminescence in fishes (apart from those whose luminescence is due to symbiotic bacteria, and those, such as Macrurids, which have open, slime-secreting glands) is of two types, namely, continuous, and intermittent. In *Chauliodus*, both types are found, the continuous light, independent of stimulation, from the cup-shaped organs on the belly, the intermittent light from all the other luminous organs, on stimulation. Dr. SKOWRON considers that the continuous light is not due to loss of control, due to approaching death, but may be either a response to a rhythmic stimulus, or a long-continued response to an earlier stimulation.

As to the means of control of luminescence, Dr. SKOWRON considers that it is due neither to hormones (as appears to be the case in *Porichthys*) nor to the varying supply of oxygen brought to the glands. He found that section of the spine instantly and irreversibly extinguished luminescence; and, remembering the slightness of the stimulus required, the spread of the response from the point of stimulus to other organs all over the body, and the short duration of response, he infers that control is due directly to the nervous system, notwithstanding BRAUER's failure to find many nerves supplying these organs.

Dr. SKOWRON's paper is interesting and important, but it leaves us as far as ever from an understanding of the purpose of these enigmatic, though widely-spread, and often highly complex, organs.

C. F. H.

K. STRUVE und W. KAIRIES. Die chemische Zusammensetzung einiger als Fischnahrung wichtiger wirbelloser Bodentiere der Nordsee. Wissenschaftliche Meeresuntersuchungen. N. F., Band XVII, Abt. Helgoland, Heft 2, Abh. 6. Kiel, 1930.

A logical sequel to a study of the nature of the food of fishes is an examination of the food value of that food. In this paper, the results of

chemical analyses of the following animals, which are used as food by fish, are given: *Nucula nucleus*, *Venus ovata*, *Tellina baltica*, *Ophiura albida*, *Echinocyamus pusillus*, *Orchestia littorea*, *Podocerus falcatus* and *Nerine fuliginosa*. The material after measurement was cleaned, weighed and dried at 105° to constant weight. Elementary analyses for C, H, and N were made and the quantity and composition of the ash found. Fat was determined by the Soxhlet extraction method and in certain cases analyses were made for calcium and chitin. From the analyses the quantity of protein, fat and carbohydrate, which are most important as food, can be calculated. These are recorded as percentages of the fresh material so that with either known numbers and sizes, or better, known weight, the quantity of the different nutritive substances can be calculated.

The work is necessarily of a preliminary nature for it is most probable that there will be important seasonal changes in the composition of the different animals, affecting their food values. In addition, the work should form a background to a study of the availability of the nutritive substances for fish. So far, enough information is not available to enable us to compare the different fish foods from the point of view of nutrition with safety, but with an extension of the work, this should become possible.

A. P. O.

A. Willer. Untersuchungen über das Wachstum bei Fischen. II, III, IV. Weitere Untersuchungen über den Einfluss äusserer Faktoren auf das Wachstum der Bachforellenbrut. Zeit. f. Fischerei. Bd. 26, S. 565—606. Berlin, 1928.

The eggs of the trout are normally incubated in water rich in oxygen and in the absence of light. The author shows that a diminution in the pressure of oxygen equivalent to about one third of its normal value markedly delays the rate of development and is liable to produce high mortality. If the amount of oxygen per litre of water falls to 1.7 c.c., the larvae die within the first month after hatching. When eggs are incubated in an oxygen-rich water and exposed to light, the effects on development are similar to those produced by a diminished oxygen supply, although the effect of light is more obvious during the early stages of development than during the later stages. The effects of diminished oxygen and of light are additive.

It seems to us that, since growing fish do not appear to use more oxygen per gram per hour than fish which are not growing, the effect of oxygen lack on the growth rate must be of a secondary nature and be dependent on a general disturbance of metabolic activity. It would be of interest to know how far the rate of development of the eggs is dependent on the amount of oxygen available for absorption from the environment.

J. G.

A. Willer, W. Quednau und A. Keller. Untersuchungen über das Wachstum von Fischen. V. Untersuchungen über den Einfluss des Alters der Elterntiere auf das Wachstum der Bachforellenbrut. Zeit. f. Fischerei. Bd. 38, S. 167—188. Berlin, 1930.

The absolute size of the offspring from the eggs of a female trout is independent of the age of the male fish from which the spermatozoa are

derived. The authors used eggs from nine selected female fish whose ages varied from three to eight years and samples of these eggs were fertilized by spermatozoa from males whose ages varied from four to nine years. In every case the size of resultant fish, six weeks after the end of larval life, was roughly proportional to the age of the female parent. From females of eight years old the average dry weight of a single offspring (153 days after fertilisation) was 16 mg.; from females seven years old, 14.7 mg. and from females four years old the average weight of the offspring was 10 mg. These differences appear to be correlated with the larger size of the eggs which are laid by older females.

J. G.

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Prepared by the Editor with the assistance of Miss THURSBY-PELHAM.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. ALLEN's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted (Price, 1 Kr.).

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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